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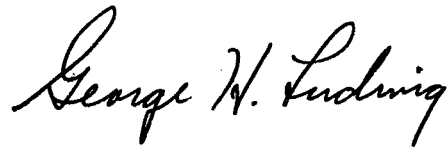
Supersedes All Previous Editions and Supplements

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

PREFACE

The Orbiting Geophysical Observatory (OGO) Bibliography with its Supplements is published to provide the OGO experimenters with a convenient reference of published and unpublished scientific and technical papers, articles and other documents on the OGO scientific results, experiment instrument design, and spacecraft design and operation. Its primary goal is to facilitate and encourage the early exchange of information among the experimenters to help in meeting one of the OGO primary objectives, the correlation of data from a large variety of related experiments.

Any recommendations for making this document more effective in achieving that goal would be appreciated.

A handwritten signature in black ink, reading "George H. Ludwig". The script is fluid and cursive, with the first letters of each word being capitalized and prominent.

George H. Ludwig
OGO I, III Project Scientist

FOREWORD

This bibliography contains the material first published in the *OGO Program Bibliography*, October 1966, and in its two supplements (NSSDC 67-20 and NSSDC 67-33). Also contained in this volume are new citations collected since the publication of Supplement 2. The principal sources of material for the bibliography are the NASA/GSFC OGO Project Office, the NASA Scientific and Technical Information Facility, the NASA/GSFC Library, and individual OGO experimenters.

Copies of "preprints" of listed articles are distributed to *all OGO experimenters*. Other requests for copies should be directed to the authors. Copies of referenced articles and reports should be obtained directly from the authors or other sources. As a further aid in obtaining documents, NASA accession numbers* are given when available.

Additional supplements will be published as sufficient numbers of new citations become available. The next cumulative edition of the bibliography will be published in January 1969.

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BIBLIOGRAPHY GENERAL

Alfonsi, P. J., "A Simulation of the Response of the OGO Spacecraft Structure to the Launch Acoustic Environment," presented at AIAA Unmanned Spacecraft Meeting, Los Angeles, California, March 1-4, 1965 (AIAA Publication CP-12), 60-67, 1965. A65-19498.

ABSTRACT: Discussion of the acoustic test program of the Orbiting Geophysical Observatory (OGO) conducted at Langley Research Center in the sound field generated by the 9' by 6' thermal structures wind tunnel. The specific purpose of the program was to experimentally determine the magnitude and spectra of the vibration response of the OGO spacecraft structure due to the associated acoustic environment. The description includes the test facility, the test specimen, instrumentation, test requirements, and test procedure. The maximum and minimum octave band levels in the sound field generated by the thermal structures wind tunnel and recorded at the reference location during the six "low level" runs are presented. It is shown that the repeatability of the sound field is excellent with no more than 1-db variation in the data from these runs. It is also shown that the overall rms vibration levels at the base of the interstage fitting on the Agena ring were virtually the same for each "low level" run. Plots of acceleration spectral density, including overall levels, are also presented.

Beachley, N. H., L. B. Martin, and D. D. Otten, "Testing OGO's Attitude Controls," *Control Engineering*, 11, 93-97, October 1964. A64-27303.

ABSTRACT: Description of the attitude-control system for the Orbiting Geophysical Observatory (OGO) satellite and the facilities and procedures used in performing prelaunch operational checks. When individual attitude-control axes are decoupled sufficiently to permit testing the control systems one at a time, the single-axis simulator technique used on OGO is said to offer an excellent simulation of the low-torque environment of space, at low cost compared to other approaches. A suspended table (on a long, low-torsion wire servoed at the top to reduce torsion to the vanishing point) reportedly required 170 hr to accumulate a position error of 1 millirad.

Berman, A. L., "Observatories in Space," *Scientific American*, 209, 29-37, August 1963. A63-20243.

ABSTRACT: Discussion of different types of existing and proposed orbiting observatories. The difficulties involved in making astronomical observations from terrestrial stations are discussed, including the blocking out of most of the electromagnetic spectrum by the Earth's atmosphere. The means by which orbiting stations would overcome these difficulties are noted. Briefly discussed are the Orbiting Geophysical Observatory (OGO), scheduled for launching in 1963, the Orbiting Solar Observatory (1962 Zeta 1), the Orbiting Astronomical Observatory (OAO), to be launched in 1964, and a hypothetical Orbiting X-ray Observatory (OXO). The problems involved in constructing an X-ray telescope for the latter observatory are discussed, including the work of Baez on methods of focusing X-ray beams.

Bikle, F. E., and J. B. Rohrs, "Dynamic Analysis of Longitudinal Oscillations of SM-68B Stage 1 (POGO)," Martin Company Technical Operating Report CR64-71, BSD TR 65-179 March 1964.

ABSTRACT: Part I—The linear model developed in this report is capable of predicting stability of the physical system responsible for the Titan II longitudinal oscillation. The utility of the model extends to development of various stabilizing fixes installed on the fuel and oxidizer suction systems. The model leads to a stability criteria stated in terms of system parameters.

Part II—The linear model developed in Part I successfully simulated three of the four important longitudinal oscillation characteristics. The model successfully predicted the following:

1. Onset of oscillations;
2. Convergence of oscillations;
3. Magnitude of closed-loop measurement ratios, such as

$$P_{os}/g, P_{fs}/g, P_{od}/P_{os}, P_{fd}/P_{fs}, P_c/g.$$

Since the model is linear, it cannot predict acceleration amplitudes.

Britner, R. O., "Ground Systems Test Plan OGO," July 1965, GSFC X-535-65-275, Preprint.

ABSTRACT: The OGO Ground System Test Plan (GSTP) has been prepared so that each STADAN station will have the information necessary to perform tests on their equipment to assure readiness for support of the Orbiting Geophysical Observatory (OGO). The two basic functions performed by the stations are command transmission and data acquisition. This document will describe methods for checkout of both of these basic systems. This document is applicable to both EGO's and POGO's (Eccentric and Polar OGO's respectively). This document is a reference source and each station may adopt portions of it as it sees fit for pre-pass procedures and other tests.

Coates, R., C. Creveling, E. Habib, M. Mahoney, and C. Stout, "Telemetry Data Processing for the Eccentric Orbiting Geophysical Observatory Satellite," 21 October 1963. N64-11812.

ABSTRACT: The Eccentric Orbiting Geophysical Observatory (EGO) is being designed to have PCM telemetry data rates of 1000, 8000, or 66,000 bits/sec selectable by ground command. This satellite will have on-board data storage for low-speed data (1000 bits/sec) plus about 40 percent ground station coverage of each orbit for data acquisition at any of the bit rates. The program planned for the first EGO satellite anticipates receiving an average of 6000 bits/sec for a period of 6 months, or a total of about 10^{11} bits. The high-speed data processing system for this high volume of data consists of two processing lines plus a large-scale digital computer. The processing lines convert the analog recordings of the PCM telemetry signals to digital magnetic tapes in computer format. The computer then performs quality control and decommutation of the data into separate digital tapes for each experimenter. Author

Coyle, R. J., and J. K. Stewart, "Real Time Quick-Look Analysis for the OGO Satellites," *American Federation of Information Processing Societies, Spring Joint Computer Conference, Washington, D. C., April 1964, Proceedings*, 25, 125-138, 1964. A64-24447.

ABSTRACT: Description of the programming system (exclusive of the tracking and orbit determination) for Orbiting Geophysical Observatory (OGO) satellites. The system is divided into two distinct parts: the real time monitor control, and experiment processors. The monitor control is further divided into three sections: the schedule program, monitor processors, and interrupt processors. Definitions are given of the functions and characteristics of these various sections. It is felt that the presented techniques to minimize the execution time of a powerful real-time monitor and to allocate reusable storage in a flexible manner indicate the inherent efficiency of a real-time approach.

Data Systems Engineering Section, "Operation and Maintenance Manual for OGO Command Decoder," GSFC X-545-65-339, Preprint.

ABSTRACT: This manual contains the operational and maintenance requirements for the OGO command decoder designed and developed by the Goddard Space Flight Center of the National Aeronautics and Space Administration (NASA). Included in this manual are physical and functional descriptions, operating procedures, theory of operation, preventive and corrective maintenance, and appropriate illustrations, diagrams, and schematics. Specific information can be located by consulting the table of contents or list of illustrations.

Davis, R. B., and E. T. Wiggins, "Automation for Spacecraft Ground Support Equipment," Space Technology Laboratories, Preprint.

ABSTRACT: The increasing complexity of spacecraft requires the development of more sophisticated test equipment in order to perform accurate and rapid system evaluation. This paper briefly describes the approach to automation of equipment for controlling and monitoring the tests of the Orbiting Geophysical Observatories from assembly of the spacecraft and integration of experiments through the launch phase. This equipment combines manual and automatic modes of operation to achieve flexibility with relative simplicity. A brief description of the OGO Spacecraft, the Data Handling System, and a detailed discussion of the Semi-Automatic Ground Support Equipment is presented.

Glaser, P. F., "The Orbiting Geophysical Observatory Communication and Data Handling Systems." *National Telemetry Conference, Proceedings, May 23-25, 1962, II*, New York, Institute of Radio Engineers, 1962. A63-14700.

ABSTRACT: Description of the construction of the orbiting astronomical observatory and its communications and data handling subsystems and telemetry equipment. The wideband digital telemetry system uses a single analog-to-digital converter with 8-bit accuracy for all the analog output experiments carried. The gating function between the analog experiment output and the analog-to-digital converter is located in the data system to minimize interface between the data system and the experiment. The interface wiring from the analog output to the digital telemetry system is a single line. The output must remain within zero and 5 volts and must have sufficiently low impedance to be unaffected by gate and line impedances during comparison time. In order to provide optimum digital experiment telemetry interface and still allow varying types of experiments to be carried without modification of the telemetry system, all digital data processing and accumulation are performed in the experiment.

Glaser, P. F., and E. R. Spangler, "Inside the Orbiting Geophysical Observatory," *Electronics*, 36, 61-65, February 1963. A63-13629.

ABSTRACT: Description of some of the equipment to be carried on board the Orbiting Geophysical Observatory (OGO). Detailed treatment is given to the battery charging system; the communications system, which will use three tracking transmitters and three wide-band transmitters for telemetry; and the digital and the analog data-handling assemblies.

Glaser, P. F., and E. R. Spangler, "The Electronics of the Orbiting Geophysical Observatory," Space Technology Laboratories, Preprint.

Gleghorn, G. E., "The Engineering Design of the Orbiting Geophysical Observatories" 129th Annual Meeting of the American Association for the Advancement of Science, Special Astronautics Symp. held at the Franklin Institute, December 27, 1962, 11-32. N63-15168.

ABSTRACT: The Orbiting Geophysical Observatory (OGO) spacecraft standard configuration has been designed to provide an attitude-stabilized platform with the proper mechanical and thermal environment, electric power, and telemetry equipment to accommodate a variety of experiments on each launch. Two Solar Oriented Experiment Packages (SOEP) for each solar array are provided for those experiments that must be oriented toward the sun; two Orbit Plane Experiment Packages (OPEP) are mounted on a shaft perpendicular to the solar array shaft for those experiments that must be oriented parallel to the plane of the orbit. Long and short booms are extended from the body of the spacecraft to accommodate experiments whose sensitivity or look angle requires that they be isolated from other portions of the observatory; and two opposing faces of the spacecraft body are provided for instrumentation that must either look toward or directly away from the earth. In addition, a portion of the interior has been kept clear of spacecraft equipment to accommodate large experiments. The engineering design of the supporting structure, thermal control system, power supply, attitude control system, and communications and data handling equipment includes a sufficient margin to permit the operation of the spacecraft's subsystems in a variety of orbits.

Gleghorn, G. J., "The Engineering Design of the Orbiting Geophysical Observatories," American Association for the Advancement of Science, and American Astronautical Society, Symposium on Scientific Satellites-Mission and Design, Philadelphia, Pa., December 27, 1962, *Scientific Satellites-Advances in the Astronautical Sciences*, 12, 149-174, 1963. A63-21528.

ABSTRACT: Description of the systems and subsystems design of the OGO, an attitude-stabilized spacecraft designed to provide support for 150 lb of scientific experiments when placed in a variety of orbits around Earth. The spacecraft incorporates an active thermal-control system, a wideband telemetry system with both real-time and data-storage capability, and a silicon solar-cell power supply. Stabilization techniques provide for specific orientations which are part of experiment requirements, and for removal of sensors when necessary from the immediate vicinity of the spacecraft. The systems test station and checkout provisions are detailed, and the completed mobile ground-support station is illustrated.

Gleghorn, G. J., and J. W. Lindner, "Magnetic Considerations in the Design and Testing of the OGO and Pioneer Spacecraft," International Astronautical Federation, International Astronautical Congress, 16th, Athens, Greece, September 13-18, 1965. A66-15919.

ABSTRACT: Discussion of some aspects of the magnetic design of the Orbiting Geophysical Observatory (OGO) and the Pioneer solar probe spacecraft as typical examples of problems in satellite design. The characteristics of some commonly used detectors are discussed, and representative data from satellite and space probe measurements are presented. These are shown to establish the basis for magnetic design and test requirements for the OGO and Pioneer programs. Topics discussed include instrumentation, magnetic environment of OGO and Pioneer, criteria for magnetic properties of spacecraft, mechanical equipment, electronic components, permanent magnets, electric currents, test methods, assembly magnetic tests, and observatory tests. Test data from OGO and Pioneer spacecraft have demonstrated that it is possible to design and build complex spacecraft which satisfy stringent magnetic requirements consistent with the measurement of magnetic fields in space.

Goldsmith, T. C., "Electrical Systems Considerations of Orbiting Geophysical Observatory (OGO) Experiments," May 1966, GSFC X-722-66-184, Preprint.

ABSTRACT: Experiments designed for flight on the Orbiting Geophysical Observatory are required to meet exacting specifications in the electrical interface area. These notes are intended to explain and substantiate some of the more troublesome of these interface specifications and are concerned with the electrical aspects of flight hardware, ground support equipment, and experiment qualification and testing. The material was written during OGO-E experiment development and contains some procedural and policy information which may not be entirely applicable to other OGO programs.

Heindl, J. C., and R. J. Belanger, "OGO Solar Array Drive and Shaft Support Bearing Tests," September 1962. N63-12405.

ABSTRACT: A series of tests were performed to provide design information on materials and lubricants for ball bearings to be used in the space environment. The loads, speeds, and modes of operation were chosen to be representative of those anticipated in the OGO Solar Array Drive and Shaft Support Bearings. Both R-4 size and 1-13/16-in ID bearings were tested at 10^{-7} mm of Hg and speeds of from 1 to 4 rpm for one month with instantaneous torques automatically recorded. The bearings were all 440C CRES alloy. The retainer materials tested included sintered bronze, 416 CRES, Delrin, DUROID 5813, and a phenolic. The lubricating coatings investigated were gold plating, molybdenum disulfide, and a vacuum deposited multi-layer film, CBS Laboratories' #CDL 5940. The results indicated the most satisfactory performance was obtained using gold-plated balls, races, and a gold-plated 416 CRES retainer, all burnished with MoS₂ in conformance with STL Process Specification PR1-1. Author

Jeter, I. E., Ed., *Scientific Satellites. Advances in the Astronautical Sciences, 12*, American Association for the Advancement of Science, and American Astronautical Society, Symposium on Scientific Satellites-Mission and Design, Philadelphia, Pa., 255, December 27, 1962. A63-21522.

ABSTRACT: Collection of papers dealing with present and proposed satellite programs for scientific experimentation in outer space. The satellites discussed include Topside Sounding satellites, the Orbiting Geophysical Observatories, the Orbiting Solar Observatories, Advanced Orbiting Solar Observatories, and the Orbiting Astronomical Observatory. Emphasized are descriptions of systems and subsystems designs, mission objectives, and the related instrumentation. The papers are individually abstracted and indexed in this issue.

Kleiger, L. B., "Design of the Orbiting Geophysical Observatory Data Handling System," *Spaceborne Computer Engineering Conference, Proceedings, New York, Institute of Radio Engineers*, 1962, 19-26. A63-17150.

ABSTRACT: Discussion of the data-handling system of the OGO wideband telemetry, designed to provide the flexibility required for a universal satellite. The advantages of the concept of a universal system capable of handling various combinations of experiments for telemetry transmission under various orbital conditions are outlined. It is indicated that the data-handling system could process up to 552 outputs

from 50 different experiments, as well as nearly 400 spacecraft measurement outputs. A block diagram of the data-handling system is presented.

Krausz, A., "Power Sources," *Space Communications*, edited by A. V. Balakrishnan, McGraw-Hill Book Co., 213-250, 1963. A64-11240.

ABSTRACT: General considerations regarding power requirements for satellites or spacecraft carrying communications or data-processing equipment. The primary energy sources available are described, and methods of converting primary energy to usable electrical energy are discussed in some detail, including photovoltaic energy conversion, thermionic conversion, and batteries and fuel cells. Briefly described is the electric-power-supply subsystem for the orbiting geophysical observatory (OGO).

Krausz, A., and R. L. Robinson, "The Electric Power Supply of the Orbiting Geophysical Observatory," AIAA Unmanned Spacecraft Meeting, Los Angeles, California, March 1-4, 1965 (AIAA Publication CP-12). A65-19528.

ABSTRACT: Review of the design requirements of the Orbiting Geophysical Observatory (OGO) spacecraft electrical power subsystem. The major problems of the design requirements are identified. The batteries, solar array, power supply controls, and performance in space are considered. It is shown that a number of innovations were incorporated into the OGO power supply in order to meet the wide range of design constraints. The following are concluded to be the innovations: the capability for the use of ground commands to control operation of the power supply and to modify operating conditions to meet varying orbital conditions; the use of a partial shunt regulator for controlling solar array output; a battery charge control method which is simple to mechanize yet assures complete recharge under varying conditions and prevents operation which would cause battery degradation; development of a lightweight solar array, utilizing beryllium, which can withstand a 2-hr eclipse and cyclic temperatures from 80° to -160°C; and development of a lithium-filled heat sink for power transistors which is thermally independent of the spacecraft and which limits transistor temperatures to the same values. It is hoped that the described solutions will be useful in improving the design of power supplies for future spacecraft. Author

Ludwig, G. H., "The Orbiting Geophysical Observatories," repr. from *Space Sci. Rev. (Dordrecht)*, 2, 175-218, 1963. N64-15554.

ABSTRACT: The Orbiting Geophysical Observatories and the supporting ground equipment are designed to conduct large numbers of diverse experiments. Configured to meet scientific requirements, the observatories include six booms to support detectors away from disturbances generated in the main body. Five degrees of freedom allow the orientation of experiments relative to three references—the earth, the sun, and the orbital plane. Power, thermal control, and data-handling subsystems provide for the proper operation of the experiments and telemetry of the data. Ground stations receive these data, which are then processed into a form suitable for use by the experimenters. The systems have been designed to make available a standard spacecraft and support equipment that can be used repeatedly to carry large numbers of easily integrated experiments in a wide variety of orbits. Author

Ludwig, G. H., "The Orbiting Geophysical Observatories," NASA TN D-2646, 49, March 1965. N65-18616.

ABSTRACT: The Orbiting Geophysical Observatories and the supporting ground checkout equipment, data acquisition and tracking stations, and data processing equipment are designed to conduct a large number of diverse experiments in space. The observatories include six booms to support detectors away from disturbances generated in the main body of the spacecraft. Five degrees of freedom allow the orientation of experiments relative to three references—the earth, the sun, and the orbital plane. Power, thermal control, and data handling subsystems provide for the proper operation of the experiments and the telemetering of the data. Ground stations receive the data which are then processed into a form suitable for use by the experimenters. The systems were designed to make available a standard type of spacecraft and support equipment which can be used repeatedly in launching a large number of easily integrated experiments in a wide variety of orbits. Author

Ludwig, G. H., "Relative Advantages of Small and Observatory Type Satellites," presented at COSPAR Symp., Buenos Aires, May 1965. N65-29783.

ABSTRACT: Both the relatively small Explorer and the large Orbiting Observatory classes of scientific satellite have advantages which need to be considered carefully when a new space experiment is to be performed. The small satellite offers greater choice in tailoring the orbit to the experiments. The smaller size simplifies the electrical, magnetic, and radiated interference problem, since fewer operating components are involved. It provides greater ease in testing and scheduling, and permits a shorter pre-launch lead time. The larger observatory permits the conduct of more complex or larger numbers of related experiments for the more detailed study of the co-relationships between the numerous space phenomena. Since it is less highly integrated, standard experiment/spacecraft interfaces can be defined to simplify the experiment design and integration problems. The larger size permits the use of higher capacity and more flexible data systems and more precise active orientation systems. Operational efficiency is higher, since the data from a large number of experiments can be recorded and processed simultaneously. It is concluded that both types should continue to be used to meet the varied requirements of the space sciences program. Author

Ludwig, G. H., and W. E. Scull, "The Orbiting Geophysical Observatory, a New Tool for Space Research," NASA TN D-1450, 18, August 1962. N62-15053.

ABSTRACT: In early spacecraft, the systems and experiments were highly integrated assemblies designed to fully utilize the limited weight capabilities of the launching vehicles. This high degree of mechanical and electrical integration required that each satellite or probe be completely redesigned for each new mission. Now that larger launching vehicles are available, observatory-type spacecraft are being developed which make the integration of large numbers of complex experiments more practical. These spacecraft consist of basic structures, electrical power, thermal control, attitude control, and data handling systems. Typical of these is the Orbiting Geophysical Observatory (OGO) which will carry 150 pounds of experiments to conduct investigations within and immediately outside the earth's magnetosphere and exosphere. It is being developed with well defined, simple interfaces between the experiments and spacecraft systems so that experiments developed at different laboratories may be integrated into the spacecraft with minimum of effort. The capabilities of OGO are discussed and the experiments which are being developed for the first OGO launching are listed. Author

Mahoney, M., and J. Quann, "Visual Presentation of the Motion and Orientation of an Orbiting Spacecraft (OGO)," NASA TN D-2918, 17, July 1965. N65-29296.

ABSTRACT: The motion and orientation of an orbiting spacecraft are normally represented by vectors and angles in the various coordinate systems (celestial inertial coordinates, spacecraft coordinates, geodetic coordinates, etc.); and it is difficult to interpret spacecraft behavior in terms of actual orbital position and attitude. Motion and orientation information for a particular satellite (OGO) have been analyzed by the 1107 computer (Univac) and the 4020 microfilm plotter (Stromberg-Carlson), and numerical data on satellite behavior were made available. The data were then used to create a motion picture film illustrating satellite attitude in orbit. Author

Matzen, L. R., R. H. Renken, and S. Y. Yu, "Simulation of Spacecraft Deployment Dynamics," AIAA Simulation for Aerospace Flight Conference, Columbus, Ohio, August 26-28, 1963. A63-20594.

ABSTRACT: Description of the analytical and experimental simulations of the complex unfolding motion of the multisegment 21-ft booms of the Orbiting Geophysical Observatory (OGO). The angular positions of the boom segments are obtained from the analysis as a function of time. This technique provides determination of deployment patterns which minimize structural loads and do not cause clearance problems. Other useful by-products of the analytical simulation are deployment times and the motion of the spacecraft main structure during deployment. The analytic simulation results in equations of motion which are nonlinear and are not subject to small-angle restrictions. The equations also include the effects of viscous damping. The expressions were formulated so that the simulation could be applied to a large number of deployment problems. Included as parameters in the expressions are hinge spring torque, segment weight, length, the radius of gyration, and the deployment release angle for each segment. The experimental simulation was achieved by using air bearings, which counteracted the effects of gravity and minimized friction.

The experimental results correlate well with the analytical predictions. The hinge locking sequences were identical and the difference in predicted and measured deployment times were small.

Mercanti, E. P., "The Orbiting Geophysical Observatories Brochure for Experimenters," GSFC, Preliminary, December, 1961.

Monroe, G. E., Jr., R. K. Fox, and W. E. Faragher, "The Advantages of Independent Reliability Assessment," AIAA-SAE-ASME, Aerospace Reliability and Maintainability Conference, 1st, Washington, D. C., May 6-8, 1963. A63-16115.

ABSTRACT: Demonstration of the objective use of reliability calculations in two specific examples of independent ("nonhardware" organizations) reliability assessments. The first example (the Shillelagh missile system) is selected to illustrate an overall reliability model to be used in predicting the reliability of a complete system. The second example—the Orbiting Geophysical Observatory (OGO)—illustrates that part of reliability assessment in which more detailed engineering attention is brought to bear on the inherently weak areas, in this instance, the communications and data-handling system of the NASA OGO spacecraft.

Network Engineering & Operations Division, "Operations and Maintenance Manual OGO-ATS Command Console," March 1966, GSFC X-530-66-194, Preprint.

ABSTRACT: This manual contains information to assist personnel who install, operate, and maintain the Orbiting Geophysical Observatory/Advanced Technological Satellite (OGO/ATS) Command Console (hereinafter also referred to as the Command Console). It is divided into seven sections as follows:

Section 1: Introduction, general description, and technical characteristics.

Section 2: Installation information and procedures.

Section 3: Operating procedures, description of controls and indicators, and command patching instruction.

Section 4: Functional description and detailed analysis of flow and logic diagrams.

Section 5: Preventive maintenance schedules; maintenance, alignment, disassembly and repair procedures.

Section 6: Parts lists.

Section 7: Flow and logic diagrams.

Sections 3, 4, 5 and 7 are written with the assumption that the reader has knowledge of digital theory, flow diagrams, and logic diagrams, and is familiar with digital transistor techniques. An illustration of standard and nonstandard logic symbols used with the logic diagrams is provided as part of the introduction to section 4.

Newell, H. E., "Space Science and Satellite Applications Programs," Report to the Space Science Board, 68, December 1962. N63-20242.

ABSTRACT: Mission capabilities and design descriptions are given for a number of satellites and launch vehicles. The satellites include such spacecraft as (1) the Orbiting Geophysical, Orbiting Solar, and Orbiting Astronomical Observatories; (2) interplanetary monitoring probes; (3) international satellites such as Ariel and Alouette; (4) the Ranger satellite series; (5) the Surveyor and Mariner spacecraft; (6) Orbiting Biological Observatories; (7) passive satellites, such as Echo 1; (8) active satellites, such as Relay, Telstar, and Syncom; and (9) meteorological satellites such as the Tiros series, and the Nimbus satellites. The launch vehicles include (1) sounding vehicles, such as Aerobee, Nike-Apache, Nike-Cajun, and Argo rockets; (2) small and medium vehicles, such as Scout, Delta, Thor-Agena, Atlas-Agena, and Atlas-Centaur; and (3) large vehicles, such as the Saturn C-1, the Saturn C-1B, and the Saturn C-5.

Otten, D. D., "The Design of the Attitude Control System for the Orbiting Geophysical Observatory," *International Astronautical Federation, International Astronautical Congress, 14th, Paris, France, September 25-October 1, 1963, Paper 31*, 30. A63-25654, N64-11893.

ABSTRACT: The attitude control system maintains one body axis of the satellite in alignment with local vertical. In addition, the angular orientation of the satellite body about local vertical is controlled, along with a single-degree-of-freedom solar array, to maintain the solar cells perpendicular to the sun's rays. Further, a package (OPEP) free to rotate with respect to the body about local vertical is kept at all times aligned in the orbit plane. Mission requirements are stated, and, from these, control laws for each of the

five axes of control are deduced. Response requirements are then stated, and the foundation for the control system design is established. The sensors and control torque sources for the OGO ACS are described and their choice justified. The control system logic is presented, and the details of the control system design and sizing are given. Author

Otten, D. D., "Attitude Control for an Orbiting Observatory: OGO," *Control Engineering*, 10, 81-85, December 1963. A64-10864.

ABSTRACT: Discussion of the challenging task of designing a seemingly simple attitude-positioning control system for a scientific satellite, from hard, irreducible specifications. In the orbiting geophysical observatory satellites, positioning must be accurate and nearly continuous for a design life of one year. High accuracy in continuous positioning is not consistent with the total energy that can be carried as compressed gas. The solution for OGO is a classic example of the control engineer's mating of electronics, optics, electromechanics, and pneumatics in a reliable system.

Paddack, S. J., R. A. Devaney, and H. E. Montgomery, "OGO Earth Acquisition," NASA TM X-55002, 164, May 1964. N64-23517.

ABSTRACT: To "acquire" the earth means that the earth will be visible to the satellite in a certain fashion. The technique for predicting earth acquisition is a mathematical method that is developed into a computer program. Through the use of the program it is possible to predict when, after a reference time, the earth can be acquired by a particular satellite in a given orbit. The technique is a function of the kind of earth-search and acquisition device, the orbit, the launch date, and the time of day. The technique is applied and results are shown for two satellites in the OGO family—namely, for the Eccentric Orbiting Geophysical Observatory, EGO S-49, and for the Polar Orbiting Geophysical Observatory, POGO S-50. Author

Peterson, M. C., "The Orbiting Geophysical Observatory Test Program," Institute of Electrical and Electronics Engineers, International Conference and Exhibit on Aerospace Support, Washington, D. C., August 4-9, 1963, *IEEE Transactions on Aerospace, AS-1*, 362-373, August 1963. A63-23249.

ABSTRACT: Description of the Orbiting Geophysical Observatory Spacecraft and the electrical and mechanical checkout procedures and equipment used in its qualification and acceptance testing. The Integrated Systems Test approach incorporating semi-automatic test programming and spacecraft evaluation is described, after disclosure of previous test cycles and the test program objectives. Specific tests on the attitude control, power, and communications and data handling spacecraft subsystem are discussed, with consideration given to mechanical handling and test fixtures.

Schanbacher, W. A., "Advanced Concepts in System Evaluation Through Telemetry," presented to the AIEE Aero Space Transportation Conference and Summer General Meeting, Col. 1962 CP 62-1304.

ABSTRACT: The paper describes a philosophy of testing which removes a basic obstacle to accurate system evaluation. The philosophy, that of observing a vehicle's configuration during its evaluation, has recently become practical; and a current spacecraft program, the Orbiting Geophysical Observatory, referred to as OGO, is utilizing its command and telemetry link to support the principle. The advantages and methods of employing these techniques are described in significant detail.

Characteristics of the OGO Command and Telemetry loop and the methods of testing each of the vehicle subsystems are reviewed through the use of block diagrams showing system and test configurations. Measurements and measurement display techniques are shown for both manual and semi-automatic modes of operation. The increased flexibility afforded the equipment by these techniques is also described. Evaluating systems in this manner provides a significant step toward the realization of a universal semi-automatic test station. Concluding remarks will be directed toward a brief review of total system trade-offs in terms of performance, cost, schedule, vehicle weight, and adaptability to military programs.

Schanbacher, W. A., and C. A. Schorken, "The Orbiting Geophysical Observatory Test and Support Program," presented at the AIAA Space Flight Testing Conference, Cocoa Beach, Florida, March 18-20, 1963. N64-10077.

ABSTRACT: The following areas of the testing and support program are discussed: (1) objectives of the test program; (2) written procedures; (3) system tests; (4) electrical tests and support equipment:

attitude control, power system, communication and data handling, and automatic test loop; and (5) mechanical tests and support equipment: spacecraft handling equipment, mechanical testing, mechanical alignment and tests, pneumatic tests, and design qualification.

Scull, W. E., "The Mission of the Orbiting Geophysical Observatories," 129th Annual Meeting of the American Association for the Advancement of Science, 1-10, December 27, 1962. N63-15167.

ABSTRACT: The Orbiting Geophysical Observatories program has two objectives. The primary objective is to conduct large numbers of significant, diversified experiments for making scientific and technological measurements within the earth's atmosphere, the magnetosphere, and cislunar space to obtain a better understanding of earth-sun relations and of the earth as a planet. A secondary objective is to design, develop, and have available for launching at regular intervals a standard observatory-type oriented spacecraft consisting of a basic system design that can be used repeatedly to carry large numbers of easily integrated experiments in a wide variety of orbits. As a design objective for the standard spacecraft, it is desired that the spacecraft be capable of reliable operation for a period up to one year in a wide variety of orbits from near-earth circular to highly elliptical cislunar. The current program consists of two missions: the Eccentric Orbiting Geophysical Observatory (EGO), which will be launched from the Atlantic Missile Range in late 1963; and the Polar Orbiting Geophysical Observatory (POGO), which will be launched in early 1964 from the Pacific Missile Range. Author

Scull, W. E., "The Orbiting Geophysical Observatories," *International Symposium on Space Technology and Science*, 5th, Tokyo, Japan, September 2-7, 1963. A65-14349.

ABSTRACT: Brief review of the development and objectives of the orbiting geophysical observatories. The following subjects are treated: (1) program objectives, (2) spacecraft, (3) structure, (4) thermal control, (5) power supply, (6) attitude control, (7) communications and data handling, (8) tracking and command, (9) data acquisition and control, (10) data processing, and (11) experiments. The experiments to be carried on EGO and POGO are listed in tables.

Scull, W. E., "The Mission of the Orbiting Geophysical Observatories," *Scientific Satellites. Advances in the Astronautical Sciences*, 12, 127-148, 1963. A63-21527.

ABSTRACT: Review of the design and objectives of the OGO program. The primary objective is to conduct large numbers of experiments concerning the atmosphere of the Earth, the magnetosphere, and cislunar space, in order to obtain information of the Earth-Sun relationship. A secondary objective is to design, develop, and make available for launchings at regular intervals a standard observatory-type oriented spacecraft consisting of a basic system design that can be used repeatedly to carry large numbers of easily integrated experiments in a wide variety of orbits. The current program consists of two missions: the Eccentric Orbiting Geophysical Observatory, and the Polar Orbiting Geophysical Observatory.

Scull, W. E., and G. H. Ludwig, "The Orbiting Geophysical Observatories," *IRE, Proceedings*, 50, 2287-2296, November 1962. A63-10333.

ABSTRACT: Description of the Orbiting Geophysical Observatories which are systems designed to fulfill a primary objective of conducting large numbers of significant, diversified experiments for making scientific and technological measurements within the Earth's atmosphere, the magnetosphere, and cislunar space, to obtain a better understanding of Earth-Sun relationships and the Earth as a planet. Configured to meet scientific requirements, the observatories include six booms of different lengths for experiments requiring locations at a distance from the main body. Five degrees of freedom allow the capability of continuously orienting solar and antisolar, geocentric and antigeocentric, and orbital experiments within relatively close limits. Weighing 1,000 lb, of which 150 lb are exclusively experiments, the observatories have potential of growth to 1,500 lb and carrying more experiments. Designed to include five basic subsystems of structure, stabilization and control, power supply, communications and data handling, and thermal control, the observatories have well-defined interfaces for experiments. This basic design fulfills a secondary objective of having available for launching at regular intervals, a standard-type spacecraft consisting of a basic design that can be used repeatedly to carry large numbers of easily integrated experiments in a wide variety of orbits.

Stambler, I., "The OGO Satellites," *Space/Aeronautics*, 39, 70-77, February 1963. A63-12124.

ABSTRACT: Description of the design of the OGO (Orbiting Geophysical Observatory) satellites, which are intended to provide data on the intensity and behavior of charged particles in the Earth's atmosphere, on the Earth's magnetic field, and on other atmospheric phenomena. Study of the radiation belt produced by nuclear explosions at high altitude is included in the program. The EGO and POGO satellites, part of the OGO program, intended as elliptically orbiting and polar orbiting satellites, respectively, are also described. Special problems raised by the basic box-structure satellite concept are reviewed, showing how the requirements of a wide range of experiment packages set the basic conditions for attitude control, material selection, and thermal design. Details are given about methods devised to meet the special needs of short-run satellite production.

Webb, J. E., "Our Orbiting Observatories," *Grumman Horizons*, 2, Spring, 1962. N63-13292.

ABSTRACT: Orbiting observatories are discussed. The Orbiting Solar Observatory is a stabilized space platform designed for continuous observation of that giant nuclear reactor, our sun, and its atmosphere in the X-ray, ultraviolet, and infrared regions of the spectrum. One of the instruments provided by NASA's Goddard Space Flight Center, for example, is an X-ray spectrometer. Sounding rocket experiments have shown that X-rays are generated by the sun. Knowledge of the intensity and "hardness" of this X-radiation is important in understanding the nature of the physical processes that take place in the sun. That knowledge, in turn, may have its practical applications in helping us to harness the power of hydrogen fusion for the benefit of mankind. A special feature of this observatory is its ability to point continuously at the center of the sun to an accuracy of two minutes of arc, or less. Our first Astronomical Observatory is scheduled for launching in 1965. The primary experiments for the first three Astronomical Observatories will be centered on stellar astronomy in the ultraviolet range. Instruments of later observatories will be trained on the sun and the planets. An active life of a year or more is desired for each observatory. All will be launched into circular orbits 500 miles above the earth. The Geophysical Observatories will be in 1963 and 1964. They will be used to study the earth's atmosphere, ionosphere, geomagnetic field, radiation belt, energy particles, cosmic rays, and the transition region between the ionosphere and true space.

Webb, J. E., "1963: The Greatest Year in Space," *Aerospace*, 1, 2-7, March 1963. A63-15354.

ABSTRACT: Brief presentation of the proposed space program for the 1963-1964 period for unmanned investigation in space, advanced research and technology, manned space flight, and space applications. These include such programs as the Orbiting Geophysical Laboratory, the first demonstration of electric propulsion in space (Project SERT), first flight tests of both stages of the Saturn I booster, and the first satellite in synchronous orbit. Some basic policies which guide NASA in its relationship with U. S. industry are briefly discussed.

Wiard, William D., "OGO Attitude Computations," GSFC X-564-66-90, March 1966, Preprint.

Winthrop, A. S., "Implementation of a Design Review Program," *Institute of Radio Engineers Annual Seminar, 3rd, Reliability of Space Vehicles, Los Angeles, California, October 26, 1962*, Third Annual Seminar on Reliability of Space Vehicles, Western Periodicals Co., North Hollywood, California, 16, 1962. A63-13537.

ABSTRACT: Description of the theoretical development and actual implementation within a divisional organization of a comprehensive design review program. Successful application to the Orbiting Geophysical Observatory program is reported. The initial success of the pilot operation suggests a company-wide application.

OGO-1 DESCRIPTION OF EXPERIMENTS

4901 SOLAR COSMIC-RAYS, Dr. Kinsey A. Anderson, UCLA

This experiment consists of scintillation type detectors to measure the form and time variations of the energy spectrum from a few Mev up to 90 Mev, investigate spatial inhomogeneities of the solar-proton flux upon their arrival at the earth, search for proton fluxes attributable to flares on the back side of the sun, monitor X-rays from the sun, measure the flux and energy of photons which arise in proton-producing flares, and measure protons in the galactic cosmic radiation during the approach to solar minimum.

4902 ELECTROSTATIC PLASMA ANALYZER, Dr. J. H. Wolfe, ARC

The findings of this experiment will further understanding of the lower energy (a few to a few thousand electron volts) particles and their relationship to other geophysical, solar, and cosmic phenomena. The distribution of plasma particles is particularly important in understanding the distributions of magnetic fields in space.

4903 PLASMA FARADAY CUP, Dr. H. J. Bridge, MIT

This experiment is concerned with properties of the solar plasma in the tens of thousands of electron volts range, and their influence on the earth's magnetosphere. Scientific objectives include measurements of the following quantities: proton flux, proton-energy spectrum, and direction of the flux, as well as temporal and spatial variations of these quantities, and correlation of the above data with measurements of the magnetic field.

4904 POSITRON SEARCH AND GAMMA-RAY SPECTRUM, Dr. T. L. Cline, GSFC, and Dr. E. W. Hones, Jr., IDA

This experiment will investigate the possible existence of low-energy positrons trapped in a permanent or transitory manner in the radiation belts, and the possible arrival of low-energy solar or interplanetary positrons at the edge of the earth's magnetic field. This experiment will be able to measure, over a wide dynamic range, the flux of gamma rays in the energy range from 30 kev to 1.2 Mev.

4905 TRAPPED RADIATION, SCINTILLATION COUNTER, Dr. A. Konradi, GSFC

This experiment will provide further studies of the temporal and spatial variations of the particle intensities, pitch-angle distribution, and energy spectra of electrons and protons, and will answer questions such as: particle lifetimes, processes by which trapped particles are lost, and the sources and accelerating mechanisms of the trapped particles.

4906 COSMIC-RAY ISOTOPIC ABUNDANCE, Dr. F. B. McDonald, GSFC

A cosmic-ray telescope and set of Geiger Muller telescopes will analyze the charge and energy spectrum of the primary cosmic radiation to assist in determining the amount of interstellar material through which primary cosmic rays have passed between their source and the vicinity of the earth, to study the modulation mechanisms which act on the cosmic rays, and to study the charge and energy spectra of cosmic rays produced by the sun.

4907 COSMIC-RAY SPECTRA AND FLUXES, Dr. J. A. Simpson, U. of Chicago

This experiment will assist in the search for the acceleration mechanisms acting on cosmic rays and solar particles, and will study the electro-dynamic processes of solar origin which lead to the modulation of the galactic-ray flux, such as the 11-year cycle, the Forbush decreases, and the 27-day variation.

4908 TRAPPED RADIATION, OMNIDIRECTIONAL COUNTERS, Dr. J. A. Van Allen, SUI

This experiment will monitor the electron component of the outer radiation zone of the earth to determine the absolute intensity and energy spectrum as a function of time and of position (electron energies in the range 40 kev to 1.5 Mev) in a continuing effort to improve the observational foundations for

understanding the dynamics of the outer zone; i.e., acceleration, dumping, replenishment, redistribution in space, and the relationship of the outer zone to magnetic storms and aurorae.

- 4909 TRAPPED RADIATION, ELECTRON SPECTROMETER, Dr. J. R. Winckler and Dr. R. L. Arnoldy, U. of Minn.

This experiment employs two primary detector systems. A swept magnetic-field electron spectrometer will make a precise measurement of the electron-energy spectrum in the range 50 keV to 4 MeV. An ionization chamber and G-M counter will assist in the determination of the electron, proton, and X-ray fluxes. The experiment will assist in the study of the injection, trapping, and loss mechanisms acting in the earth's radiation belts.

- 4910 TRIAXIAL SEARCH COIL MAGNETOMETER, Dr. E. J. Smith, JPL, and Dr. R. E. Holzer, UCLA

The objectives of this experiment are to investigate the nature of extremely low-frequency variations (0.01 to 1000 cps) in the terrestrial geomagnetic field, in the interplanetary field, and in the vicinity of the interface between them and to investigate the relationship between the fluctuations in these three regions of space and the simultaneous variations at the earth's surface.

- 4911 RUBIDIUM-VAPOR AND FLUXGATE MAGNETOMETER, Dr. J. P. Heppner, GSFC

A combination of component fluxgate sensors and a rubidium-vapor magnetometer is intended to provide comprehensive field measurements with a known absolute accuracy. Objectives of this experiment are to accurately measure the interaction of solar and geomagnetic field phenomena, to measure the local field sources such as ring currents, to study the rapid field fluctuations with frequency ranges covering at least four orders of magnitude, and to provide charts and mathematical descriptions for the International World Magnetic Field Survey.

- 4912 SPHERICAL ION AND ELECTRON TRAP, Dr. Rita C. Sagalyn, AFCRL

This experiment uses a spherical electrostatic analyzer to measure the concentration and energy distribution of charged particles having thermal energies.

- 4913 PLANAR ION AND ELECTRON TRAP, E. C. Whipple, ESSA

This experiment will obtain the density and energy distribution of charged particles in the low-energy or thermal ranges in the transition region between the ionosphere and the interplanetary space, and in interplanetary space, which is characterized by low particle densities.

- 4914 RADIO PROPAGATION, Dr. J. K. Hargreaves, ESSA

This experiment will make accurate measurements of the electron density along the line-of-sight by determination of the Faraday rotations of two harmonically related, linearly polarized waves. Ground stations will be able to measure the magnitude of large-scale horizontal irregularities in the electron distribution of the ionosphere and exosphere.

- 4915 ATMOSPHERIC MASS SPECTRUM, H. A. Taylor, Jr., GSFC

This experiment will obtain direct measurements of positive-ion composition in the mass range 1-50 AMU through the EGO orbit by the use of a Bennett RF mass spectrometer.

- 4916 INTERPLANETARY DUST PARTICLES, Prof. J. L. Bohn, Temple U.

This experiment will establish the velocity and mass distributions for interplanetary dust particles of micron size. The findings of this experiment will extend the mass-distribution curve out to the radiation-pressure limit, and measure the fluctuations in velocity distribution, mass distribution, and spatial densities.

4917 VLF NOISE AND PROPAGATION, Dr. R. A. Helliwell, Stanford U.

This experiment will increase the overall understanding of the VLF phenomena in the earth's magnetosphere, such as the terrestrial noise produced below a height of 70 km (atmospherics due to lightning noise generated within the earth's ionosphere and magnetosphere), VLF emissions produced by incoming solar particles, and cosmic noise of entirely extraterrestrial origin such as solar and planetary noise. The frequency range to be covered is 200 to 100,000 cps.

4918 RADIO ASTRONOMY, Prof. F. T. Haddock, U. of Mich.

The prime objective of this experiment is to measure the dynamic radio spectrum of solar radio-noise bursts. The frequency drift rate, frequency bandwidth, and duration of fast-drift solar bursts will be observed. This experiment may also observe radio bursts from the planet Jupiter. Additional observations to be made are: cosmic-noise intensity, ionospheric electron densities (50 to 500 electrons/cm³), atmospherics, auroral noise from the earth to observatory, and radio noise generated in the terrestrial ionosphere and in interplanetary plasmas. The investigations will cover the frequency ranges from 200 to 400 kc and 2 to 4 Mc.

4919 GEOCORONAL LYMAN-ALPHA SCATTERING, Dr. P. M. Mange, NRL

The Lyman-alpha glow in the night sky probably originates from either a geocorona or the interplanetary medium. To distinguish the relative contributions of these two sources, it is necessary to make measurements from great altitudes which will permit separation of the sources of the resonantly scattered light.

4920 GEGENSCHNITT PHOTOMETRY, Dr. C. L. Wolff, GSFC, and Dr. S. P. Wyatt, U. of Illinois

The question as to where the Gegenschein (counterglow) originates in space has defied solution by ground observers for nearly two centuries, and is not likely to be solved until an observation is made sufficiently far from the earth to show a parallax. This experiment will study the antisolar direction and nature of the scattering centers which produce the Gegenschein.

OGO-I EXPERIMENTS

4901 (Anderson, Solar Cosmic-Rays)

Kahler, S. W., J. H. Primbsch, and K. A. Anderson, "Energetic Protons from the Solar Flare of March 24, 1966," *Solar Physics*, 2, 179-191, 1967.

ABSTRACT: Ten to 100 MeV protons from the solar flare of March 24, 1966 were observed on the University of California scintillation counter on OGO-I. The short rise and decay times observed in the count rates of the 32 channels of pulse-height analysis show that scattering of the protons by the interplanetary field was much less important in this event than in previously observed proton flares. A diffusion theory in which $D = Mr^\beta$ is found to be inadequate to account for the time behavior of the count rates of this event. Small fluctuations of the otherwise smooth decay phase may be due to flare protons reflected from the back of a shock front, which passed the earth on March 23.

4902 (Wolfe, Electrostatic Plasma Analyzer)

Beck, C. W., II, T. B. Fryer, C. N. Burrous, and R. C. Hedlund, "Solar Wind Measurement Techniques. II-Solar Plasma Energy Spectrometers," *National Aerospace Electronics Conference, 17th, Dayton, Ohio, May 10-12, 1965, Proceedings*. A65-29239.

ABSTRACT: Description of the curved-plate electrostatic solar-plasma instruments designed by NASA for the Orbiting Geophysical Observatory and the Interplanetary Monitoring Platform. These instruments measure the flux, angle of incidence, and energy spectrum of the positive ions within the solar plasma. They are capable of detecting a flux of 10^5 protons/cm²-sec (10^{-14} amperes with a capture area of 0.5 cm²) over an energy range from 450 ev to 18 kev with an angular resolution of better than $\pm 4^\circ$. Author

Wolfe, J. H., R. Silva, and M. Myers, "Preliminary Results from the Ames Plasma Probe: IMP-I and OGO-I," presented at the April 1965 AGU Meeting, Washington, D. C.

Wolfe, J. H., R. W. Silva, and M. A. Myers, "Preliminary Results from the Ames Research Center Plasma Probe Observations of the Solar Wind-Geomagnetic Field Interaction Region on IMP-II and OGO-I," presented at the May 1965 Space Science Symposium, COSPAR, Mar del Plata, Argentina, *Space Research, VI*, 680-700, also Ames Research Center Preprint.

ABSTRACT: Recent data on the plasma characteristics in the transition region and near interplanetary space as observed by the Ames Research Center Plasma Probe on IMP-II and OGO-I are presented. The data reveal that there is, in general, less than a factor of two decrease in the convective velocity of the plasma as it passes from interplanetary space into the transition region and an accompanying increase in temperature of approximately an order of magnitude. Evidence is presented for significant plasma acceleration in the transition region as indicated by the consistent appearance of a large non-Maxwellian high energy tail in the velocity distribution. Observation of the plasma flow characteristics in the transition region show that although there is a large spread in the angular distribution, there is a consistently directed streaming of the plasma around the magnetosphere away from the subsolar region. Other features of the data are discussed which apparently question the validity of interpreting the interaction of solar plasma with the earth's field in terms of an aerodynamic analogy. A possible mechanism for the injection of high energy particles into the magnetosphere is also presented.

4903 (Bridge, Plasma Faraday Cup)

Binsack, J. H., and V. Vasyliunas, "Simultaneous Shock Compression Observed by the MIT Plasma Experiments on IMP-II and OGO-I," presented at the AGU Meeting, Washington, D. C., Vol. 48, No.1, 176, March 1967.

ABSTRACT: During the onset of the geomagnetic storm of November 15, 1964, the MIT plasma detectors on IMP-II and OGO-I simultaneously observed a compression of the shock boundary.

IMP-II was in the transition region, outbound at a Sun-Earth-satellite angle of 50° in the dawn hemisphere. The dusk side of the transition region at this time was being explored by OGO-I, which was located at $20 R_E$ on the 1800 h local time meridian. The interplanetary conditions were being monitored by IMP-I, which was well in front of the shock boundary in the subsolar direction. The simultaneous observations of the shock boundary compression and its relationship to the interplanetary stimulus will be presented. The observed compression to 85% of the average position of the boundary is shown to agree very well with the expected compression based on the increase in dynamic plasma pressure.

Binsack, J. H., and V. M. Vasyliunas, "Simultaneous IMP-II and OGO-I Observations of Bow Shock Compression," *J. Geophys. Res.*, 73, 429-433, January 1968.

ABSTRACT: The positions of both the magnetopause and the bow shock are highly variable [Holzer *et al.*, 1966; Heppner *et al.*, 1967; Moreno *et al.*, 1967]. Possible causes of this variability include changes in the properties of the medium on either side of the boundaries, as well as instabilities or waves that may be intrinsic to the boundaries themselves. Observational identification of changes, if any, in the interplanetary or magnetospheric plasmas that are associated with boundary motions and may be responsible for them is a very difficult task. A powerful new tool for the study of such changes that has become available with the recent proliferation of satellites is the use of simultaneous observations from two or more satellites at widely different points in space.

In this note we use simultaneous observations from the M.I.T. plasma probes on IMP-II and OGO-I to investigate quantitatively the question whether large-scale motions of the bow shock that occur during magnetic storms result primarily from the over-all compression of the entire magnetosphere-magnetosheath system by the enhanced solar wind dynamic pressure. Specifically, it has been possible (1) to verify that this shock motion occurs nearly simultaneously on the dawn and dusk sides of the magnetosheath and (2) to use one satellite to monitor the solar wind pressure while the other was observing the shock.

Vasyliunas, V. M., "Observations of 50- to 2000-ev Electrons with OGO-A," presented at the April 1966 AGU Meeting, Washington, D. C.

ABSTRACT: Electron fluxes in four energy intervals covering the range from 50 to 2000 ev have been studied with a Faraday cup flown aboard the OGO-A satellite. The apogee of OGO-A is at a geocentric distance of 24.4 Earth radii and solar ecliptic latitude of 35° ; data were obtained at solar ecliptic longitudes between 135° and 40° and between -40° and -135° . The data thus provide a broad survey of both the spatiotemporal and the spectral distribution of low-energy electrons. A striking difference is found between electron spectra in the magnetosphere and that in the transition region: in the magnetosphere the flux generally increases with increasing energy or peaks near 1 keV, whereas in the transition region the flux falls sharply with increasing energy (generally as a power law). In both regions the flux is highly variable in time. A summary description of observed space-time variations and some relations to geomagnetic activity will be presented.

Vasyliunas, V. M., "Low Energy Electrons in the Magnetosphere as Observed by OGO-I and OGO-III," presented at the Summer Institute, Physics of the Magnetosphere, Boston College, June 19-28, 1967. To be published in *Physics of the Magnetosphere*.

Vasyliunas, V. M., "A Survey of Low Energy Electrons in the Evening Sector of the Magnetosphere with OGO-I and OGO-III," to be published in *J. Geophys. Res.*, Vol. 73, No. 9, 2839-2884.

ABSTRACT: Observations of electrons of energy 125 ev to ~ 2 keV with the OGO-I satellite and of electrons of energy 40 ev to ~ 2 keV with OGO-III (by means of modulated Faraday cup detectors) are used to investigate the low energy electron population in the magnetosphere within the local time range ~ 17 to ~ 22 hours. Intense fluxes of these electrons are confined to a spatial region, termed the plasma sheet, which is an extension of the magnetotail plasma sheet discovered by the Vela satellites and is identified with the soft electron band first detected by Gringauz. The

plasma sheet extends over the entire local time range studied in this investigation, from the magnetospheric tail past the dusk meridian toward the dayside magnetosphere. In latitude it is confined to within 4-6 Re of the geomagnetic and/or solar magnetospheric equatorial plane, in agreement with observations already reported from the Vela satellites; no electron fluxes are detected high above the equator, not even very near the magnetopause. In radial distance the plasma sheet is terminated by the magnetopause on the outside and by a well-defined sharp inner boundary on the inside. The inner boundary has been traced from the equatorial region to the highest latitudes investigated, $\sim 40^\circ$; during geomagnetically quiet periods it is observed at an equatorial distance of 11 ± 1 Re and appears to extend to higher latitudes along magnetic field lines. Weak or no electron fluxes are found between the inner boundary of the plasma sheet and the outer boundary of the plasmasphere. Detection (by an indirect process) of the very high ion densities within the plasmasphere gives positions for its boundary in good agreement with other determinations. During periods of magnetic bay activity the plasma sheet extends closer to the earth; the inner boundary of the plasma sheet is then found at equatorial distances of 6-8 Re. This is most simply interpreted as the result of an actual inward motion of the plasma during a bay. In one case it was possible to associate the beginning of this motion with the onset of the bay and to estimate an average radial speed of ~ 12 km/sec, from which an electric field corresponding to ~ 48 kilovolts across the magnetospheric tail was inferred. Within the plasma sheet the electron population is characterized by densities from 0.3 to 30 cm^{-3} and mean energies from 50 to 1600 eV and higher, with a strong anticorrelation between density and mean energy so that the electron energy density ($\sim 1 \text{ keV cm}^{-3}$) and energy flux ($\sim 3 \text{ ergs cm}^{-2} \text{ sec}^{-1}$) show relatively little variation. The lower energies and higher densities tend to occur during periods of geomagnetic disturbance. The non-observation of electrons in regions above the plasma sheet implies an upper limit on the electron density of $5 \times 10^{-2} \text{ cm}^{-3}$ if their mean energy is assumed to be ~ 50 eV (typical of the magnetosheath) and 10^{-2} cm^{-3} if the energy is $\sim 1 \text{ keV}$ (typical of the plasma sheet). At the inner boundary of the plasma sheet there is a sharp softening of the electron spectrum with decreasing radial distance but apparently little change in the electron density. The electron energy density decreases across the inner boundary roughly as $\sim \exp(\text{distance}/0.4 \text{ Re})$ during quiet periods; during times of magnetic bay activity the energy density decreases as $\sim \exp(\text{distance}/0.6 \text{ Re})$ and there is a more complicated spatial structure of density and mean energy.

4904 (Cline, Positron Search and Gamma-Ray Spectrum)

Cline, T. L., P. Serlemitsos, and E. W. Hones, Jr., "A Double Gamma-Ray Spectrometer to Search for Positrons in Space," presented at the Eighth Scintillation and Semiconductor Counter Symposium, Washington, D. C., March 1962, *IRE Transactions on Nuclear Science*, NS-9, No. 3, 370, June 1962, also NASA Technical Note D-1464, October 1962.

ABSTRACT: The features of scintillation counting techniques allow the development of detectors which can be made to respond preferentially to chosen types of particles. One series of experiments requires the development of detectors which will identify single positrons mixed in a relatively high flux of other radiations in space. Directional detectors of positrons having energies between a few eV and a few MeV have been designed to search for admixtures of these particles in the cosmic radiation near the top of the atmosphere, in the electron population of the trapped radiation zone, and in the solar particle streams and plasma clouds in interplanetary space. These detectors, which are scheduled for flight on balloons, sounding rockets, and the Eccentric Geophysical Observatory satellite, are described in this report. The scintillation techniques involved are discussed and the analog and digital data-recovery instrumentation for each experiment is outlined.

Cline, T. L., and E. W. Hones, "Studies of Low Energy Electrons and Positrons," presented at the April 1965 AGU Meeting, Washington, D. C.

4905 (Konradi, Trapped Radiation, Scintillation Counter)

Konradi, A., "Electron and Proton Distribution in the Anti-Solar Direction as seen by Explorer 14 and OGO-I," presented at the April 1965 AGU Meeting, Washington, D. C.

4906 (McDonald, Cosmic-Ray Isotopic Abundance)

Balasubrahmanyam, V. K., K. A. Brunstein, G. H. Ludwig, F. B. McDonald, and R. A. Palmeira, "Energetic Particle Studies in the 15-75 Mev per Nucleon Interval: IMP and OGO-I," presented at the April 1965 AGU Meeting, Washington, D. C.

ABSTRACT: The second Interplanetary Monitoring Platform (IMP-II) was launched on 4 October 1964 into an orbit having its apogee at 95,000 km on the sunlit side of the earth. The first Orbiting Geophysical Observatory (OGO-I) was launched on 5 September 1964 (U. T.) into an orbit having an apogee at 148,000 km on the dawn side of the earth. Thus, both spacecraft spend appreciable fractions of their times outside the earth's magnetosphere. Included in the experiment complement on both spacecraft are dE/dx vs E experiments to measure the energy spectra of the galactic protons and alpha particles in the range 15-75 Mev/nuc. Pairs of Geiger counter telescopes are also included to observe the time variations and directional characteristics of the galactic cosmic ray flux above 30 Mev. The initial results from these experiments are presented.

The dE/dx vs E experiments have shown the proton differential energy spectrum to be rapidly falling in the lower portion of the energy interval investigated. The Geiger counters have measured a cyclic modulation of the cosmic ray omnidirectional flux. The period of this modulation was about three-quarters of a day. The details of the proton and alpha particle energy spectra, fluxes, and time variations during both quiet and disturbed interplanetary conditions are discussed. Several solar proton events have also been observed and will be discussed.

Balasubrahmanyam, V. K., D. E. Hagge, G. H. Ludwig, and F. B. McDonald, "The Multiply Charged Primary Cosmic Radiation at Solar Minimum, 1965," *J. Geophys. Res.*, 71, 1771-1780, April 1966.

ABSTRACT: A synthesis of preliminary experimental results from cosmic ray experiments flown on OGO-I, IMPs I, II, and III and high latitude Skyhook balloon flights provides charge and energy spectra extending from ~ 20 Mev/nucleon to 1 Bev/nucleon for hydrogen through neon. A multiple Geiger counter cosmic ray monitor flown on these four satellites provided information on the total Flux > 50 Mev/nucleon. The period from March through June 1965 appears to have minimum solar modulation effects and is operationally defined to be the solar cosmic ray minimum. Energy spectra for particles from H through Ne from 25 Mev/nucleon to 1 Bev/nucleon are presented. Results on the long term temporal variation of He nuclei and protons are discussed. The L/M ratio at 100 Mev/nucleon and above 600 Mev/nucleon are found to be $.29 \pm .05$ and $.30 \pm .03$. The C/He ratio at 100 Mev/nucleon is found to be $.023 \pm .005$ whereas above 600 Mev/nucleon the same ratio is found to be $.036 \pm .004$. The change in this ratio appears to suggest the deceleration of the nuclei of higher Z in the interstellar gas due to ionization.

Hagge, D. E., "The Composition of Low Energy Cosmic Rays," to be presented at the 10th International Conference on Cosmic Rays, Calgary, Canada, June, 1967.

Ludwig, G. H., and F. B. McDonald, "Cosmic Ray Experiments for Explorer XII (1961 ν) and the Orbiting Geophysical Observatory," *Goddard Space Flight Center Contributions to the COSPAR Meeting*, May 1962, NASA TN D-1669, 223-235. N63-17115.

ABSTRACT: The cosmic-ray experiment on Explorer XII consisted of a Geiger-counter telescope, a thin CsI scintillation counter, and a large-area scintillation-counter telescope. The thin scintillation counter was connected to an 8-level integral analyzer. The large-area scintillation-counter telescope, which measured the energy loss of the detected particle, was fed to a 32-channel differential pulse-height analyzer with a storage capacity of 65,535 counts per channel. Both the Geiger-counter telescope and single counter rates were telemetered. All information was multiplexed onto a single channel. Details of the instrumentation and the methods of encoding are discussed. For the first Orbiting Geophysical Observatory mission, a new scintillation-counter telescope has been developed which measures both energy loss and total energy. This furnishes excellent charge and energy resolution over an energy range from about 11 to 90 Mev per nucleon. Design details of this telescope and its associated electronic instrumentation are also presented.

Meyer, J. P., D. E. Hagge, and F. B. McDonald, "Measurement and Interpretation of the Isotopic Composition of Hydrogen and Helium Cosmic-Ray Nuclei below 70 MeV/Nucleon," GSFC X-611-67-401, preprint.

ABSTRACT: The differential energy spectra of the hydrogen and helium isotopes of the galactic cosmic radiation have been measured in 1965 and 1966 by the highly eccentric satellites OGO-I and IMP-III. The energy ranges were respectively 20 to 50 and 30 to 90 MeV/nucleon.

The measured ratio $\Gamma_d = H^2/He^4$ shows a very steep positive slope ($\geq E_{kin}^{+3}$) as a function of energy between 20 and 50 MeV/n. At 50 MeV/n, Γ_d is roughly 0.25. These results are in qualitative agreement with the measurements performed by the University of Chicago group on IMP-III. The measured ratio $\Gamma_{He} = He^3/He^4$ is roughly 0.5 at 60 MeV/nucleon, and decreases at lower energies.

In order to understand the energy dependence of Γ_{He} and especially of Γ_d (Γ_d is not affected by the solar modulation), we investigated the creation of deuterium and He^3 through fragmentation of cosmic ray and interstellar He^4 nuclei, and proton-proton reactions (assuming no injection of these isotopes at the source).

We have used a Monte Carlo technique to propagate the cosmic ray protons and He^4 nuclei from the source to the earth. A critical survey of the available cross section data has been made. The ionization loss, the energy dependence of the cross sections, the reaction kinematics have been taken into account. The elastic scattering, acceleration in space and solar modulation have not.

We have systematically tried to fit the data with different source spectra and propagation models. Our present results completely rule out a total energy, and favor kinetic energy source power spectrum. We discuss the bearing of different non-local propagation models (open model, closed model, injection at one time; different energy dependences of the mean "vacuum pathlength") on Γ_d and Γ_{He} .

Teegarden, B., "A Study of Low Energy Galactic Cosmic Rays from 1961 to 1965," NASA GSFC Technical Abstracts, Vol. 5, No. 1, Jan-Mar. 1967. X-611-67-8.

ABSTRACT: The results from a series of balloon flights beginning in 1961 and ending in 1965 are presented. Measurements of the cosmic ray intensity were made using a dE/dx and E detector sensitive to energies from 15 to 80 MeV/nucleon. The early balloon flights provided design information and also aided in the development of data handling techniques for later satellite versions of the detector which have been on IMP's I, II, and III and OGO's I and III. Proton and helium intensities at 85 MeV/nucleon are presented for the five year period covered by the balloon flight series. The behavior of the proton to helium ratio as a function of time is discussed within the framework of Parker's model for the solar modulation of cosmic rays.

In 1965 a modified version of the dE/dx and E detector with an extended energy range was flown for the first time. A cosmic ray helium spectrum from 60 to 500 MeV/nucleon measured by this detector is presented. The change in proton and helium intensities in this energy region from 1963 to 1965 is examined and compared with the results predicted by the various special cases of Parker's model.

A totally empirical atmospheric secondary proton spectrum is derived, based on simultaneous balloon and satellite measurements. This spectrum is compared with the secondary spectrum obtained from a nuclear emulsion measurement and the differences are discussed. Using our empirical secondary spectrum, we obtain an upper limit for the re-entrant albedo at Sioux Falls which is significantly less than values reported by other observers.

A measurement of the intensities of secondary deuterium and tritium was made in 1965. Using these results, we obtain a value for the global average production of tritium in the earth's atmosphere. The implications of this result regarding the problem of tritium balance in the atmosphere are discussed.

4907 (Simpson, Cosmic-Ray Spectra and Fluxes)

Comstock, G. M., C. Y. Fan, and J. A. Simpson, "Abundance and Energy Spectra of the Galactic Cosmic Ray Nuclei C, N, O, Ne, Mg, and Si from 30 to 300 Mev per Nucleon," June 1965, Preprint EFINS-65-52. Submitted for publication in *Physical Review Letters*.

ABSTRACT: We report preliminary results of an experiment which measures the individual, stripped nuclei of all the elements from carbon through silicon in the energy range ~ 30 to ~ 300 Mev per nucleon. We have determined the abundances of these nuclei and their energy spectra with the exception of N, F, Na and Al where we have determined only the upper limits of abundances. These results cover an energy range about one order of magnitude lower than has been heretofore explored. This energy region is of fundamental interest for investigating the origins of the cosmic radiations since the various tenable hypotheses predict different relative chemical abundances and energy spectra of the stripped nuclei as they undergo acceleration and as they propagate through the interstellar medium.

Comstock, G. M., C. Y. Fan, and J. A. Simpson, "Abundances and Energy Spectra for Nuclei of Galactic Origin above 20 MeV per Nucleon," *Proc., Ninth Internat. Conf. on Cosmic Rays, Vol. 1*, 4, 383-386, Physical Society, London, 1966.

ABSTRACT: The individual chemical abundances of nuclei with charge Z extending from $Z = 2$ to $Z = 14$ in the energy range to 20 to 300 Mev/nucleon have been measured in interplanetary space on the OGO-I satellite for ~ 150 hours in October and November 1964. At higher Z , two charge groups were measured, including the Fe-group. The energy spectra for C, O and Ne are shown to be remarkably flat and different from the helium spectrum measured simultaneously over the same energy/nucleon range. It is concluded that these spectral differences exist in the cosmic radiation outside the solar system. The relative abundances for $6 \leq Z \leq 14$ display an even-odd Z ratio of approximately 8:1. Li, Be and B, and the Fe-group are present with about the same relative abundances as observed at higher energies. It is suggested that the rate of particle acceleration for wide range of Z competes effectively with the rate of ionization loss at these low energies. The measurements were made with state silicon detectors and anticoincidence scintillators arranged to measure energy-loss and total energy.

Comstock, G. M., C. Y. Fan, and J. A. Simpson, "Abundances and Energy Spectra of Galactic Cosmic-Ray Nuclei above 20 Mev per Nucleon in the Nuclear Charge Range $2 \leq Z \leq 26$," Enrico Fermi Institute for Nuclear Studies, University of Chicago, *Astrophysical Journal*, 146, No. 1, Oct. 1966, also preprint EFINS 66-09.

ABSTRACT: The individual abundances of the elements helium through silicon, as well as the nuclear charge group $15 \leq Z \leq 25$, and the Fe-Ni group have been measured using a telescope composed of solid state detectors on the OGO-I satellite in the period October 1964 to June 1965. Also measured were the different energy spectra for He, B, C and O over the energy range ~ 20 to 1000 Mev per nucleon, with some integral measurements above 1000 Mev per nucleon. The spectra for Ne, Mg, and the Fe-Ni group were obtained over a narrower energy range. The experimental results are divided into two time intervals approximately six months apart in order to investigate the dependence of abundances and energy spectra upon changes in solar modulation.

The abundances of the elements in the kinetic range ~ 20 to ~ 330 Mev per nucleon are normalized to oxygen with a flux of 5.4×10^{-3} nuclei/m²-sec-sr-Mev/nucleon. The ratio of abundances of nuclei with even-to-odd nuclear charge number Z , especially in the range $6 \leq Z \leq 14$ is approximately 8:1. Li, Be and B are present down to the lowest observed energies in the approximate ratio 2:0.7:2.5. The ratio (Li, Be, B): (C, N, O) = 0.26 ± 0.04 . The abundance of the Fe-Ni group relative to C and O is nearly equal to its abundance at high energies. For nuclei $5 \leq Z \leq 14$ the differential energy spectra are remarkably independent of energy below ~ 300 Mev/nucleon. It is shown that the spectra for these nuclei, when extrapolated to the nearby interstellar medium must be continuously rising toward the lowest observed energies (~ 20 Mev/nucleon) with greater negative slopes than for the He spectrum. Experimental evidence for the galactic origin of these nuclei is presented.

The bearing of this experiment on the origin and propagation of cosmic ray nuclei is discussed, and it is pointed out that some assumptions commonly accepted are no longer tenable. Two specific alternatives are considered. It appears that energy degradation by ionization loss alone may not account for the results. It is suggested that the rate of particle acceleration for a wide range of Z competes effectively with the rate of ionization loss at these low energies. Alternatively, a discrete, and possibly nearby, source in the galaxy could account for these low energy measurements. Since the technique of using solid state devices for measuring multiply charged nuclei is novel there is a description of the instrument and the methods for analyzing the data.

Comstock, G. M., "The Low Energy Cosmic-Ray Nuclei and their Propagation in Interstellar Space," Tenth Internat. Conf. on Cosmic Rays, Calgary, Canada, *Can. J. Phys.*, in press, 1968.

Comstock, G. M., "Energy Spectra of Galactic Cosmic-Ray Nuclei with $Z \geq 2$ above 30 MeV/Nucleon in the period 1964-1965," *Bul. Amer. Phys. Soc.*, 12, 582, 1967.

Fan, C. Y., G. Gloeckler, and J. A. Simpson, "Recent Satellite Studies of Nonrelativistic Cosmic Ray Proton and Helium Nuclei," presented at the April 1965 AGU Meeting, Washington, D. C.

Fan, C. Y., G. Gloeckler, and J. A. Simpson, "Protons and Helium Nuclei within Interplanetary Magnetic Regions which Co-Rotate with the Sun," Proc., *Ninth Internat. Conf. on Cosmic Rays*, Vol. 1, 2, 109-111, Physical Society, London, 1966, also preprint EFINS 65-89.

ABSTRACT: From IMP-I measurements we showed in 1964 that fluxes of protons of >1 Mev energy appeared for several days in a sequence of six consecutive 27-day intervals. We concluded that these protons were confined within a region co-rotating with the sun which modulates the galactic cosmic radiation at the orbit of Earth with the same 27-day recurrence period. This region has persisted for more than 20 solar rotations and was observed with the IMP-I magnetometer by Ness and Wilcox to possess special characteristics. The energy spectrum of the protons in the leading and trailing sides of the co-rotating region was measured. A helium component continuously associated with the protons has been found with an energy spectrum of E^{-2} MeV/nucleon in the energy range 2 to 30 MeV/nucleon. Evidence from the OGO-I satellite indicates that the proton and helium fluxes are not only present within co-rotating regions, but are also present at lower intensity and with different spectra at all times throughout a 2.5 month period. The source for continual acceleration of these protons and helium nuclei is discussed.

Fan, C. Y., G. Gloeckler, B. McKibben, K. R. Pyle, and J. A. Simpson, "Differential Energy Spectra and Intensity Variations of 1-20 MeV per Nucleon Protons and Helium Nuclei in Interplanetary Space (1964-1966)," Tenth Internat. Conf. on Cosmic Rays, Calgary, Canada, *Can. J. Phys.*, in press, 1968.

Fenton, K. B., "A Search for α Particles Trapped in the Geomagnetic Field," *J. Geophys. Res.*, 72, No. 15, 3889-3894, Aug. 1, 1967.

ABSTRACT: Data from the University of Chicago charged-particle telescope on the satellite OGO-I for the regions of the geomagnetic field in which protons of energy 26-85 Mev are trapped have been analyzed for the presence of α particles during a period near the minimum of solar activity (1964). The region of (B, L) space sampled is that for which $1.6 \leq L \leq 3.3$ and $0.01 \leq B \leq 0.25$. From an examination of samples of data in which a total of 15,000 trapped protons were observed, it is concluded that the upper limits for the α -particle proton ratio are 1 in 1500 for the energy range 26-85 Mev/nucleon and less than 1 in 50 for the rigidity range 0.33-0.39 bv. It is inferred from the fact that the results indicate an almost pure proton source that the decay of energetic albedo neutrons must be the principal source of trapped protons at energies above 26 Mev.

O'Gallagher, J. J., and J. A. Simpson, "Anisotropic Propagation of Solar Protons Deduced from Simultaneous Observations by Earth Satellites and the Mariner IV Space Probe," *Physical Review Letters*, 1212-1217, June 27, 1966.

Simpson, J. A., "Solar Modulated and Interstellar Spectra of Galactic Cosmic Radiation," invited paper P-3, AGU, 17 April 1967, *Trans. AGU*, 48, 14, 1967.

Simpson, J. A., "High Energy Particles of Solar Origin," invited paper, American Astronomical Society, Tucson, Arizona, Feb. 1, 1968, *Astrophys. J.*, 1968.

4908 (Van Allen, Trapped Radiation, Omnidirectional Counters)

Frank, L. A., J. A. Van Allen, H. K. Hills, and R. W. Fillius, "Proton and Electron Intensities in the Earth's Outer Radiation Zone: OGO-I," presented at the April 1965 AGU Meeting, Washington, D. C.

Frank, L. A., and H. K. Hills, "OGO-I Observations of Energetic Electrons in the Earth's Magnetosphere beyond 5 Earth Radii," presented at the April 1965 AGU Meeting, Washington, D. C.

ABSTRACT: The omnidirectional intensities of electrons $E > 40$ kev, > 130 kev, and > 1.6 Mev on the evening side of the Earth's magnetosphere and to a geocentric radial distance of $\sim 23 R_E$ (Earth radii) have been surveyed with a complement of Geiger-Mueller tubes on OGO-I over the period late September through late December 1964. A local peak of electron $E > 40$ kev and $E > 130$ kev intensities has been found at low geomagnetic latitudes in the geocentric radial distance range $12 (\pm 2) R_E$ at low latitudes. The 'spikes' of intensities previously observed with Explorer 14, IMP-I, and Vela satellites are frequently present, and the frequency of occurrence of observable electron $E > 40$ kev intensities are summarized in geomagnetic, solar ecliptic, and solar magnetospheric coordinates. The rise times of these intensity spikes are often $\lesssim 10$ seconds with increases by factors of 10 to 100 in intensity. Similar rapid decreases in intensities are also observed. With decreasing radial distance below $10 (\pm 2) R_E$, and at low geomagnetic latitudes the electron spectrum $40 \text{ kev} < E < 1.6 \text{ Mev}$ rapidly hardens with respect to the spectra of the intensity spikes observed at larger radial distances and perhaps delineates the region of durable, or more permanent, trapping of electrons $E > 40$ kev.

Hills, H. K., "Observations of Electron Intensities in the Outer Radiation Zone with OGO-I," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 163, Mar. 1967.

ABSTRACT: Observations of electron ($E > 40$ kev, > 130 kev, and > 1.6 Mev) intensities in the outer radiation zone with an array of Geiger-Mueller tubes borne on OGO-I over the period extending from mid-September through December 1964 are presented. Pitch angle distributions of electrons with energies $E > 40$ kev and $E > 130$ kev are approximated by a $\sin^n \alpha$ distribution, and n typically is less than or near unity for both energies in the middle of the outer zone ($L \simeq 4-5$) at low magnetic latitudes ($\lambda_m \lesssim 30^\circ$), although temporal variations are observed; n increases at lower L values. For larger L values ($L \gtrsim 7$), n varies over a wide range; pitch angle distributions peaked at $\alpha = 90^\circ$, as well as angular distributions with two maxima, are displayed. The omnidirectional intensities of electrons ($E > 40$ kev, > 130 kev, and > 1.6 Mev) were characterized by a general decline throughout this period, concurrent with an over-all decrease in the K_p index. The temporal variations of the pitch angle distribution indices, the 2-point spectral indices, and the electron intensities over $2 \lesssim L \lesssim 9$ near the magnetic equator are summarized for the 4-month period of observations.

Hills, H. K., "Observations of Energetic Electron Intensities in the Earth's Outer Radiation Zone with OGO-I," University of Iowa Report 67-72, December 1967.

ABSTRACT: Observations of intensities of outer zone electrons obtained with University of Iowa instruments borne on the satellite OGO-I are presented for the period September through December, 1964. Omnidirectional intensities near the magnetic equatorial plane are given for electrons of energies $E > 40$ keV, $E > 130$ keV, and $E > 2$ MeV, and are characterized by short-term variations superimposed upon an overall long-term decrease. Computations of the effects of geomagnetic storms upon the distribution of intensities of those electrons with energies above the detector thresholds are summarized. Adiabatic motions are shown to be capable of causing large temporal variations in electron intensities during a magnetic storm, but the time resolution possible with the spacecraft orbit is not fine enough to allow detailed comparison of predictions and observations. The pitch angle distribution of electrons ($E > 40$ keV and $E > 130$ keV) may be approximated by the function $\sin^n \alpha$ with n generally found to be less than or about unity throughout the outer zone ($3 \lesssim L \lesssim 7$). At larger radial distances ($7 \lesssim L \lesssim 14$), the intensities of electrons ($E > 40$ keV and $E > 130$ keV) have been observed to be at a maximum in directions near parallel to the magnetic field and at a minimum perpendicular to the field.

Rao, C. S. R., "Study of the Temporal Variations of 40 keV Electrons in the Magnetosphere During and After the Magnetic Storm on April 18, 1965," University of Iowa Report 67-16, May, 1967.

ABSTRACT: Temporal variations of the intensities of electrons $E > 40$ keV during the main phase and post-storm period of a large magnetic storm which occurred on April 18, 1965 are studied in

this paper from the data obtained at high latitudes by the University of Iowa Satellite Injun IV and at low latitudes by the NASA satellite OGO-I.

The high latitude observations show a large inward movement of the cutoff boundary for trapped electrons to lower latitudes by as much as 8° . On the storm day and during the post-storm period, the cutoff latitude shows a close and direct correlation with D_{st} and inverse correlation with 3-hour K_p index. The 'slot,' which is present at an invariant latitude of 61° before the storm, disappears on the storm day and is replaced by a peak. The post-storm variations of these storm-induced electrons at higher latitudes are uncorrected with the K_p index. The intensities decay according to an exponential law. There appears to be an injection and inward diffusion of fresh electrons during the post-storm period, leading to the formation of the normal quiet day profile. Variations for precipitated electrons are generally similar.

4909 (Winckler, Arnoldy, Trapped Radiation, Electron Spectrometer)

Arnoldy, R. L., S. R. Kane, and J. R. Winckler, "Observations of Energetic Electrons with the OGO-A Ionization Chamber from the June 5, 1965 Solar Flare," presented at the April 1966 AGU Meeting, Washington, D. C.

ABSTRACT: Coincident with the reception of 108-Mc/s radio noise from a solar flare on June 5, 1965, the OGO-A ion chamber detected a burst of X radiation. About 1 hour after the X-ray burst, the count rate of the ion chamber increased by about 13%. At this time the spacecraft was outside the magnetosphere at a geocentric range of about 140,000 km. Comparison with Mariner 4 Geiger counter observations of electrons from the same flare shows that the increase in the OGO-A ion chamber rate was probably due to electrons that penetrated the chamber walls, i.e., greater than 600-keV energy. The maximum flux of these electrons seen by the OGO chamber would be 1.3 electrons/cm²-sec. Applying a simple diffusion theory model to the data where the scattering centers are static and the diffusion coefficient is proportional to r^β gives a $\beta = 1.2$. The extrapolated flux of electrons of energy greater than 600 keV at the position of Mariner 4 (1.5 AU from the Sun) from the OGO measurements near Earth for this value of β is 0.42 electron/cm² sec. This flux combined with the Mariner 4 measurements of electrons greater than 40 keV gives an electron spectrum at 1.5 AU of the form $J(>E) \approx E^{-2.7}$.

Arnoldy, R. L., S. R. Kane, and J. R. Winckler, "Energetic X-Ray Bursts from Solar Flares," presented at the American Astronomical Society Meeting on Solar Astronomy, October 3-5, 1966, Boulder, Colorado.

ABSTRACT: By means of the sensitive ionization chamber on the OGO-I and OGO-III spacecraft, more than 15 solar flare X-ray bursts in the energy range 20-50 Kev have been recorded. The present study consists of a quantitative comparison between solar radio and optical emissions coincident with the X-ray flux from these events and from about 12 events previously recorded with balloons and rockets. Detailed subjects include the rise and decay characteristics of the bursts, the proportionality between the X-ray amplitude and the radio flux in the centimetric region, the association with Type 2, 3 and 4 radio bursts and energetic particles observed from the same flare, and the physical location and characteristics of the time-coincident H_α emissive regions. In some cases the detailed time structure of the X-ray bursts may be studied by a power spectrum analysis. Preliminary results indicate:

1. A close time correlation between the centimetric radio emission and the X-rays as found previously.
2. A rough proportionality between the intensity of the X-rays and the intensity of 10 centimeter emission.
3. At least half of the 10 cm bursts of peak flux greater than $6 \times 10^{-22} \text{ w/m}^2 \cdot \text{cycle} \cdot \text{sec}$ during recording times of the satellite are accompanied by observable energetic X-ray increases. All 10 cm radio bursts above $20 \times 10^{-22} \text{ w/m}^2 \cdot \text{cycle} \cdot \text{sec}$ show detectable X-rays.

4. At least one case of energetic particle production by a flare without energetic X-rays or microwave emission.
5. Electrons of roughly the energy required for producing the X-rays by bremsstrahlung were observed directly in space following several of the bursts.

Arnoldy, R. L., S. R. Kane, and J. R. Winckler, "Energetic Solar Flare X-Rays Observed by Satellite and their Correlation with Solar Radio and Energetic Particle Emission," University of Minnesota Technical Report CR-97, June, 1967.

ABSTRACT: Ionization chambers aboard the OGO-A and OGO-B spacecrafts with a response window for x-rays between 10 kev and 50 kev have accumulated more than 6,000 hours of operation in space outside the earth's magnetosphere. Approximately thirty solar flare x-ray bursts have been detected between 5 September 1964 and 20 June 1966. These energetic x-ray bursts have been correlated with 3 and 10 cm solar radio emission and solar flare electron and proton events measured in space.

A proportionality is observed between the time integrated x-ray and radio fluxes and for a given flare the rise time, decay time and total duration of the radio and x-ray bursts are similar. Exponential time constants between 1 and 10 minutes characterize the decay. All 3 or 10 cm radio bursts greater than 80 flux units are accompanied by an x-ray event greater than 3×10^{-7} ergs $\text{cm}^{-2} \text{sec}^{-1}$ and the probability of detecting an x-ray event is negligible unless the radio spectrum includes the centimetric range of wavelengths. All but three of the x-ray events were correlated with SWF ionospheric disturbances. A number of large flare events occurred in which all of the energetic processes were observed; namely, solar protons, solar electrons, energetic bremsstrahlung and high frequency radio emission. In comparing energetic x-rays with solar particle emission the best correlation seems to exist with the solar electron events observed in space. Many solar proton events occurred without a detectable burst of energetic x-rays.

It is shown that the results are consistent with a source in the flare region consisting of an active volume in a magnetic field containing hot or energetic electrons which lose energy predominantly by collisions with a much cooler gas and produce x-rays by bremsstrahlung.

Arnoldy, R. L., S. R. Kane, and J. R. Winckler, "A Study of Energetic Solar Flare X-Rays," *Solar Physics*, 2, 171-178, 1967.

ABSTRACT: A new series of solar flare energetic X-ray events has been detected by an ionization chamber on the OGO-I and OGO-III satellites in free space. These X-rays lie in the range 10-50 keV, and a study has been made of their relationship to 3 and 10 cm radio bursts and with the emission of electrons and protons observed in space. The onset times, times of maximum intensity and total duration are very similar for the radio and X-ray emission. Also, the average decay is similar and usually follows an exponential type behavior. However, this good correlation applies most often to the 'flash' phase of flares, whereas subsequent surges of activity from the same eruption may produce microwave emission or further X-ray bursts not closely correlated. An approximate proportionality is found between the total energy content of the X-rays and of the 3 and 10 cm integrated radio fluxes. These measurements suggest that the X-ray and microwave emission have a common energizing process which determines the time profile of both. The recording of electrons greater than 40 keV by the Interplanetary Monitoring Probe (IMP satellite) has been found to correlate very well with flares producing X-ray and microwave emission provided the propagation path to the sun is favorable. There is evidence that the acceleration of solar protons may not be closely associated with the processes responsible for the production of microwaves, X-rays, and interplanetary electrons.

The OGO ionization chamber responds to energies (10-50 keV) intermediate between the soft X-rays giving SID disturbances (1-10 keV) and energetic quanta previously measured with balloons (50-500 keV). Proposed source mechanisms should be capable of covering this range of energies including the most energetic quanta occasionally observed.

Arnoldy, R. L., S. R. Kane, and J. R. Winckler, "The Observation of 10-50 Kev Solar Flare X-rays by the OGO Satellites and Their Correlation with Solar Radio and Energetic Particle Emission," paper presented at IAU Symposium No. 35, Budapest, Hungary, September 4-8, 1967, U. of Minn. Technical Report CR-107.

ABSTRACT: More than 70 cases have been observed of energetic solar flare x-ray bursts by large ionization chambers on the OGO satellites in space. The ionization chambers have an energy range between 10 and 50 Kev for x-rays and are also sensitive to solar protons and electrons. A study has been made of the x-ray microwave relationship and it is found that the total energy released in the form of x-rays between 10 and 50 Kev is approximately proportional to the peak or total energy simultaneously released in the form of microwave emission. For a given burst the rise time, decay time and total duration are similar for the 10-50 Kev x-rays and the 3 or 10 cm radio emission. Roughly exponential decay phases are observed for both emissions with time constants between 1 and 10 minutes. All 3 or 10 cm radio bursts with peak intensity greater than 80 solar flux units are accompanied by an x-ray burst greater than 3×10^{-7} ergs $\text{cm}^{-2} \text{sec}^{-1}$ peak intensity. The probability of detecting such x-ray events is low unless the radio spectrum extends into the centimetric range of wavelengths. The best correlation between cm- λ and energetic x-rays is observed for the first event in a flare. Subsequent structure and second bursts may not correspond even when the radio emission is rich in the microwave component. A very good correlation exists between the occurrence of large SID events (importance-3) and energetic x-rays. The overall correlation for importance 1, 2 and 3 is 55%. Almost 90% of the x-ray bursts were accompanied by known SID events. The mechanism for the energetic x-rays is shown to be bremsstrahlung probably of fast electrons on a cooler plasma. The mechanism for the radio emission is basically uncertain. However, if it is assumed to be synchrotron radiation then a relationship is developed between density and magnetic field which meets the observed quantitative results. One finds, on the average, that 5×10^{-54} joules $\text{m}^{-2} (\text{CPS})^{-1}$ of microwave energy at earth are required per electron at the sun to provide the radio emission for the various events.

A strong correlation between interplanetary solar flare electrons observed by satellite and x-ray bursts are shown to exist. This correlation is weak for solar proton events. One may infer a strong propagation asymmetry for solar flare electrons along the spiral interplanetary magnetic field.

Arnoldy, R. L., S. R. Kane, and J. R. Winckler, "An Atlas of 10-50 Kev Solar Flare X-Rays Observed by the OGO Satellites 5 September 1964 to 31 December 1966," U. of Minn. Technical Report CR-108, January, 1968.

Kane, S. R., R. L. Arnoldy, and J. R. Winckler, "Cosmic Ray Measurements with an Ionization Chamber Experiment Aboard the OGO-A Satellite," presented at the December 1964 AGU Meeting, Seattle, Washington.

ABSTRACT: The University of Minnesota ionization chamber on OGO-A is mounted on a boom extending 4 feet from the main body of the spacecraft so that it is essentially in free space. The chamber is a 7-inch-diameter sphere of 32-mil aluminum with 50-lbs/in² Argon filling. A resetting drift-type vacuum tube electrometer records the ionization current. The OGO-A satellite was launched on September 5, 1964, into an elliptic orbit with apogee and perigee at a geocentric distance of about 155,000 km and 6800 km, respectively. Preliminary data now available give 56×10^{-3} normalized pulse per second at a geocentric distance of 154,000 km and a geomagnetic latitude 32.5° . A similar chamber flown the same day (September 24, 1964) at Minneapolis measured 29×10^{-3} normalized pulse per second at the balloon altitude of 6.8 millibars. The significance of the relative values in space and in the atmosphere will be discussed. The above measurement is probably an upper limit for galactic cosmic ray ionization, because at the time of measurement the satellite may not be completely outside the magnetosphere and the shock front.

Kane, S. R., R. L. Arnoldy, and J. R. Winckler, "Cosmic Ray Studies by Ion Chambers Outside the Magnetosphere," presented at the April 1965 AGU Meeting, Washington, D. C.

Kane, S. R., and R. L. Arnoldy, "Cosmic Ray Measurements by Ion Chambers in Free Space Since 1960," presented at the 1965 Midwest Cosmic Ray Colloquium, Chicago.

Kane, S. R., J. R. Winckler, and R. L. Arnoldy, "Studies of Primary Cosmic Rays with Ionization Chambers," presented at the September 1965 UPAP Cosmic Ray Conference, London. *Proc. of the Phys. Soc.*

ABSTRACT: It is shown that the response of ion chambers in the atmosphere and in free space is peaked over narrow rigidity intervals; these are 1.5-2.5 GV, 2.5-3.5 GV, and 3.0-4.0 GV for free space, high latitude balloon and Minneapolis balloon chambers, respectively. Using these results and measurements made with the Pioneer V, Mariner II and OGO-A ion chambers, the rigidity dependence of the long term modulation during 1960-1965 is found to be consistent with the form $P^{-\beta}$, where $\beta \simeq 0.8$. The solar cycle effect at 10 g cm^{-2} as measured by balloon flights at Minneapolis and high latitudes is presented. A phase lag of about one year between the total ionization and sunspot numbers exists throughout the cycle. A correlation plot of the high latitude balloon ionization rate and the Deep River neutron monitor for 1958-1965 shows a smooth relationship between the two rigidity ranges. The rigidity dependence of the short-term modulation as measured with space ion chambers in several cases is shown to be different from the long-term. The 'turn-up' in ionization in the atmosphere at high latitudes observed at solar minimum can be attributed to the presence of low energy S nuclei in the primary radiation at solar minimum. The peak ionization intensity of the present solar minimum appears to have occurred in May 1965.

Kane, S. R., J. R. Winckler, and R. L. Arnoldy, "Response of Ion Chambers in Free Space to the Long Term Cosmic Ray Variations from 1960 to 1965," U. of Minn. Technical Report CR-80, Sept., 65, *J. Geophys. Res.*, 70, 4107, 1965.

ABSTRACT: Differential response curves and mean rigidity of response are computed for an ion chamber in free space using the cosmic-ray spectrum at solar minimum and maximum observed by independent cosmic-ray measurements. The response is found to be confined predominantly to the rigidity interval 1.5-2.5 bv during the entire solar cycle and is consistent with the observed modulation of He nuclei at these rigidities. The corresponding rigidity intervals for ion chambers flown on balloons at high latitudes and at Minneapolis are 2.5-3.5 bv and 3.0-4.0 bv, respectively. Using these results and the measurements made with ion chambers aboard the Pioneer 5 (1960), Mariner 2 (1962), and OGO-A (1964-1965) spacecrafts, ion chambers flown on balloons at high latitudes and at Minneapolis, and the He nuclei detectors, the rigidity dependence of the long-term variation during 1960-1965 is found to be consistent with the form p^{-B} , where $B \approx 0.8$. For the sub-periods 1960-1962 and 1962-1964, B is about 0.8 and 1.4, respectively.

Kane, S. R., J. R. Winckler, and R. L. Arnoldy, "Latitude and Local Time Dependence of Iso-Intensity Contours for Electrons with Energies Greater than 700 kev in the Outer Radiation Zone," presented at the April 1966 AGU Meeting, Washington, D. C.

ABSTRACT: In the outer radiation zone, the OGO-A ion chamber responds primarily to electrons above 0.7 Mev. Iso-intensity plots in the outer zone determined from the chamber data during the period September 1964 to September 1965 are presented in the R - λ and R - ϕ planes, where R , λ , and ϕ are, respectively, the geocentric distance, geomagnetic latitude, and local time. In the R - λ plane the iso-intensity contours can be approximately fit with a $\cos^2 \lambda$ dependence, suggesting that, if the equatorial pitch angle distribution of the particles is isotropic, the particle shells are dipolar in shape up to about 45° magnetic latitude. The iso-intensity contours are also presented in the geomagnetic equatorial plane. These contours are, in general, found to be closer to the Earth on the night side compared with the noon side. For example, the iso-intensity contour for 2×10^3 electrons/cm² sec is found to be at about 9 Earth radii on the noon side and at about 8 Earth radii on the midnight side.

Kane, S. R., and D. J. Hofmann, "Difference in Total Ionization Rate of Solar Particles Inside and Outside the Magnetosphere," to be presented at the April 1968 AGU Meeting, Washington, D. C.

ABSTRACT: Identical ionization chambers aboard the satellites OGO-I and OGO-III are utilized in a comparison of the total ionization rate due to solar particles in front of the magnetosphere and in the magnetospheric tail at 15-20 earth radii.

The ionization chambers consist of a seven-inch diameter spherical aluminum shell with a wall thickness of 0.81 mm (proton cutoff - 12 MeV). The two units have been compared in flight by simultaneously measuring the galactic cosmic ray background. The ionization rates are in agreement to within 1% using the pre-flight laboratory calibrations. Although no information can be

obtained as to the type of particle or its energy spectrum, the high degree of accuracy in intercomparison and the high degree of sensitivity ($0.01 \text{ protons/cm}^2\text{-sec}$ at 20 MeV) make the ionization chamber a useful tool for studying the spatial characteristics of the radiation.

During the period from August 28, 1966 to September 30, 1966, a series of six distinct solar particle events were observed aboard OGO-III. Data from the OGO-I chamber were obtained during short periods when the satellite was operating. Data from the times of simultaneity are presented and the following results are established:

(a) During the early phases of an event, the ion chamber outside the magnetosphere indicates a higher ionization rate than inside the magnetosphere.

(b) During the decay phase the two sets of data are in average agreement; however, data from outside the magnetosphere tends to have more structure than that inside the magnetosphere.

(c) From the observed roll modulation the degree of anisotropy is found to be considerable outside the magnetosphere. Data from inside the magnetosphere are presently being analyzed for anisotropies.

Kane, S. R., "Application of an Integrating Type Ionization Chamber to Measurements of Radiation in Space," Ph. D. thesis, December, 1967, also U. of Minn. Technical Report CR-106.

ABSTRACT: An integrating type ion chamber experiment, using a resetting drift-type electrometer and designed to fly on the OGO-I and III satellites is described. The chamber is demonstrated to have an accuracy and stability of $\sim 1\%$ during its operation in space over a period of nearly three years.

The minimum energy for penetration by protons and electrons is 12 and 0.6 MeV respectively. The response to 40 KeV electrons (through bremsstrahlung) is about $10^{-7} \times$ (response at energies $> 600 \text{ KeV}$). The response to x-rays in 10-150 KeV range is peaked at $\sim 20 \text{ KeV}$; below 10 KeV the response is $\approx 10^{-2} \times$ (response at 20 KeV). For 1 particle $\text{cm}^{-2} \text{ sec}^{-1}$ of 20 KeV photons, electrons with energy $\gtrsim 1 \text{ MeV}$, and minimum ionizing nuclei with charge Ze the pulsing rate of the chamber is respectively 0.2, 7.0, and $5.5 Z^2 \text{ NPPS (Normalized Pulses Per Second)} \times 10^3$.

The OGO-I and III ion chamber measurements reported here cover the period 10 September, 1964-2 July, 1966, a period following the minimum in solar activity. The cosmic ray maximum, as determined from these measurements, occurred during 11-15 May, 1965 when the ion chamber rate in free space was $65.5 \text{ NPPS} \times 10^3$. For this time the total chamber rate computed from the "known" cosmic ray spectrum is $74 \text{ NPPS} \times 10^3$, the contributions from protons, He-nuclei, S-nuclei, electrons and nuclear interactions being about 31, 18, 33, 5 and 13 percent respectively. The difference of 12% between the total computed and observed rates could be due to a number of known factors.

The relationship between the free space ion chamber and Deep River neutron monitor during March 1960-May 1965 is found to be linear: fractional change in free space chamber $\approx k \times$ (fractional change in Deep River monitor), where $K \approx 4.5$. After May, 1965 K is < 4.5 which implies a hysteresis effect.

The differential response curve of the OGO chamber for the primary cosmic rays is peaked at about 1 and 2 BV at solar minimum and solar maximum respectively. Most of the response of an ion chamber is found to be concentrated in a rather narrow rigidity interval of the primary spectrum, the precise interval depending on the location of the chamber:

Free space	1.5 - 2.5 BV
High latitude (10 mb)	2.5 - 3.5 BV
Minneapolis (10 mb)	3.0 - 4.0 BV

These results give the rigidity dependence of the modulation consistent with $p^{-0.9}$. (period 1960-1965, $1.5 \leq P \leq 4.0 \text{ BV}$).

At high latitudes variation of the chamber rate with altitude was computed taking into account the earth's shadow effect and the observed chamber rate in free space. At balloon altitudes the computed rate is found to be lower than the observed rate; the difference is maximum ($\sim 100\%$) at solar maximum and is presumably due to the secondaries produced in the atmosphere.

Fluctuations of $\sim 5\%$ magnitude, observed in the free space chamber rate averaged over about 90 seconds, can be explained in terms of the statistical fluctuations in (a) number of primaries

passing through the chamber, (b) number of nuclear interactions in the chamber, (c) energy deposited in individual interactions and (d) heavy nuclei stopping inside the chamber gas. No single process was found to be the dominating factor.

Pfitzer, K. A., and J. R. Winckler, "A Magnetic Electron Spectrometer Flown on the OGO-A Satellite," presented at the December 1964 AGU Meeting, Seattle, Washington.

ABSTRACT: A magnetic electron spectrometer was flown on the OGO-A satellite on September 5, 1964. The satellite was injected into an orbit having a perigee of 6875-km Earth center, an apogee of 155,000 km, and an inclination of 31° to the equator. The spectrometer consists of a vertically and horizontally focusing electromagnet which bends the electrons through 65° into a heavily shielded plastic scintillation crystal. The magnetic field of the magnet is varied from a residual of 20 to 4000 gauss every 2.7 sec. The geometrical factor of the slit is 8.6×10^{-3} sterad cm^2 . The light output of the crystal is pulse-height analyzed by a phototube and a window discriminator that is stepped along with the magnetic field to give the following energy channels: 50-120, 120-290, 290-690, 690-1700, and 1700-4000 kev. The background due to electron bremsstrahlung, protons, and cosmic rays is measured by going through an analysis cycle with the magnetic field turned off. A preliminary analysis of data gives spectra throughout the radiation belts. At an $L = 5.5$ and $\lambda = 40^\circ$, for example, the directional intensities in electrons/ cm^2 -sec-ster is as follows: 4.7×10^4 between 50-120, 4.5×10^4 between 120-290, 3.0×10^4 between 290-690, 4.9×10^3 between 690-1700, and 2×10^2 between 1700-4000 kev. The spectra as functions L , λ , and pitch angle are being evaluated.

Pfitzer, K. A., and J. R. Winckler, "Energy Spectra of Electrons in the Radiation Belts from 50 Kev to 4 Mev," presented at the April 1965 AGU Meeting, Washington, D. C.

Pfitzer, K. A., S. R. Kane, and J. R. Winckler, "The Spectra and Intensity of Electrons in the Radiation Belts," presented at the May 1965 Space Science Symposium, COSPAR, Mar del Plata, Argentina. Published in *Space Research VI*.

ABSTRACT: A magnetic spectrometer measuring electrons in five channels between 50-4,000 kev and an integrating ionization chamber were launched into an eccentric orbit on September 4, 1965 on the OGO-A satellite. Electron spectra, pitch angle distributions, and total ionization are measured throughout the inner and outer belts. These measurements show the radiation region to be separated into two belts by a very pronounced slot near $L = 3$. The slot is always deep for electrons above 290 kev, but during times of magnetic disturbance may not be a clear feature for 50-120 kev electrons. The slot extends throughout all electron pitch angles and appears especially pronounced now during solar minimum.

Typical fluxes observed by these detectors are:

	$L = 1.7$	$L = 4.0$
50-120 kev	3.0×10^7 electrons/ cm^2 sec	1.6×10^6 electrons/ cm^2 sec
120-290 kev	3.1×10^7 electrons/ cm^2 sec	1.7×10^6 electrons/ cm^2 sec
290-690 kev	2.0×10^7 electrons/ cm^2 sec	2.8×10^5 electrons/ cm^2 sec
690-1700 kev	2.2×10^6 electrons/ cm^2 sec	1.8×10^4 electrons/ cm^2 sec
1700-4000 kev	2.3×10^5 electrons/ cm^2 sec	1.5×10^4 electrons/ cm^2 sec
ionization	1.0×10^4 Roentgens/hr.	1.6×10^1 Roentgens/hr.

In the inner zone these fluxes are observed to be quite stable, and the spectrum steepens as L increases from 1.3 to 3.0. In the outer zone the fluxes and spectra are very dependent on magnetic activity.

Pfitzer, K. A., and J. R. Winckler, "Time and Space Variations of Electrons in the Inner and Outer Zones during the Fall of 1964 and 1965," presented at the April 1966 AGU Meeting, Washington, D. C.

ABSTRACT: A magnetic electron spectrometer measuring electrons in five energy channels between 50 and 4000 kev was launched into a highly eccentric orbit on September 5, 1964, on the OGO-A satellite. The experiment has operated successfully for more than a year. During this period, the spectra of electrons in the inner and outer zones were measured. In the inner zone the spectrum was measured as a function of time, L, and equatorial pitch angle. The time decay of the inner zone electrons is observed. For example, the spectrum of L equal 1.7 with equatorial pitch angle 80° steepened during the 10-month period beginning September 1964 and ending June 1965. The 50- to 120-kev electron flux decreased 50%, the 120- to 290-kev electron flux decreased 55%, the 290- to 690-kev electron flux decreased 60%, the 690- to 1700-kev electron flux decreased 70%, and the decrease in the 1700- to 4000-kev electrons could not be obtained accurately. In the outer zone the spectrum is dependent on position and on magnetic activity. The spectra and fluxes are mapped against modified L shells in the outer zone. The modifications take into account the known distortions of the field due to currents in the boundary of the magnetosphere. During magnetically quiet times the spectrum is flattest at about $L = 4$ and increases in steepness for larger distances. During magnetic activity at $L = 4$, there is a large increase in the low-energy flux and a decrease in the high-energy flux.

Pfitzer, K. A., and J. R. Winckler, "The Decay and Injection of Artificial and Natural Electrons in the Inner Zone," to be presented at the April 1968 AGU Meeting, Washington, D. C.

ABSTRACT: A five channel magnetic electron spectrometer measuring electrons from 50 Kev to 4 Mev flown on the OGO-I and OGO-III satellites studied the long term time and space variations of the inner zone from September 1964 to December 1966, a period of low solar activity. Before September 2, 1966 electrons having energies greater than 290 Kev at L's less than 1.8 are observed to follow the decay curves of the Starfish electrons. 290-690 Kev electrons have decay times of 350, 450 and 450 days for L's of 1.3, 1.5 and 1.7 respectively. The decay rates are energy as well as L dependent, the higher energy electrons decaying more rapidly than the lower energy electrons.

The September 2, 1966 solar flare, one of the first large disturbances of the new solar cycle, was observed to inject electrons of energy less than 690 Kev to L's as low as 1.3; whereas, no increase in the flux was observed for electrons of energy greater than 690 Kev for L's less than 2.0. The number of electrons added to the inner zone between 50-690 Kev by the above event is independent of L, the percentage increase, however, varies from 40% at $L = 1.3$ to two orders of magnitude at $L = 2.4$. The large increase for $L > 2.0$ decays rapidly such that by mid October 1966 post-storm fluxes differ from the pre-storm fluxes by less than 50%. This "new" inner zone then resumes its "slow" decay as observed during the two years prior to the September 2, 1966 event. All electrons above 690 Kev below $L = 1.8$ can still be referred to as Starfish electrons, whereas those having energy less than 690 Kev are now primarily of natural origin throughout the entire inner zone.

Winckler, J. R., "Energy Changes of Outer Zone Electrons," presented at the April 1965 AGU Meeting, Washington, D. C.

Winckler, J. R., "The Energy Exchange Processes for Electrons in the Magnetosphere," presented at the May 1965 Space Science Symposium, COSPAR, Mar del Plata, Argentina.

ABSTRACT: Measurements on satellites in the magnetosphere and space probes when considered together lead to the conclusion that the high intensity fluxes of electrons in the outer radiation zone are energized inside the magnetosphere. Presumably most of these electrons then die by entering the atmosphere. Both the acceleration and loss mechanisms occur with great intensity during magnetically disturbed periods. However, significant gain and loss of energy can be observed during periods of magnetic quiet. This paper will summarize recent measurements of the electron spectral changes in the outer zone and its meaning in terms of energy gain and loss. Recent data has been obtained on the first NASA Orbiting Geophysical Observatory of electrons between 50 Kev and 4 Mev using a magnetic electron spectrometer. The Mev range electrons are characterized by a quick depletion during magnetic activity and a slow recovery during subsequent periods. Low energy electrons show large fluctuations and may increase markedly at the time of magnetic storms. The new measurements also confirm earlier results which showed that magnetic activity tends to concentrate the energetic electrons near the magnetic equator.

Winckler, J. R., J. R. Manzano, and R. H. Callender, "The Response of High-Altitude Ionization Chambers during the 1954-1965 Solar Cycle," presented at the April 1965 AGU Meeting, Washington, D. C.

ABSTRACT: During the 1954-1965 solar cycle, ionization chambers have been used on balloons at high altitude for investigating the intensity variations of primary cosmic rays. Ionization chambers on space probes have been used to investigate the gradient of intensity of galactic radiation in the solar system. Ionization chambers have also been used to compare Forbush decreases with the solar cycle variation and for investigating many types of radiations. In free space the ionization rate has been shown to be consistent with the detailed knowledge of the spectra and composition of the primaries. In balloon measurements where detailed interpretations are usually impossible, response curves have been determined from latitude surveys in a manner similar to sea level neutron monitors. Thus, the solar cycle spectrum changes may be predicted by ion chamber readings and are found to agree with directly measured spectra. In addition, the mean rigidity of response may be determined. The values for OGO-A, high-latitude balloons, Minneapolis balloons, and high-latitude neutron monitors are, respectively, 2.1, 2.5, 3.2, and 15.0 bv at sunspot minimum; and 3.5, 3.6, 3.8, and approximately 15 bv, respectively, at sunspot maximum. By means of approximately 300 balloon flights, the solar cycle effect has been determined at Minneapolis and at high latitude. The cosmic-ray minimum lags the sunspot maximum by approximately 18 months with a rapid drop and slow recovery. A careful study shows that between 3 and approximately 40 bv all rigidities change with the same phase, and that regression plots between various detectors show little or no hysteresis over the solar cycle. Gradient measurements with ion chambers on Pioneer 5 and Mariner 2 have shown no significant effect between the orbits of Earth and Venus, although galactic radiation had recovered a major amount between the two measurements.

4910 (Smith, Holzer, Triaxial Search Coil Magnetometer)

Brody, K. I., R. E. Holzer, and E. J. Smith, "OGO-I Search Coil Magnetometer Measurements in the Geomagnetic Tail," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 168, Mar. 1967.

ABSTRACT: The OGO-I search coil magnetometer is capable of measuring two components of the dc magnetic field by virtue of its 12-second period rotation. A series of observations were made in the geomagnetic tail. A marked decrease of the amplitude of the dc field and a change of direction were observed in the region where the neutral sheet was expected. Frequencies above 1 hz were of relatively low amplitude throughout the tail as compared with the magnetosheath or the magnetosphere. During the intervals of observation the K_p index was 4 or less.

Brody, K. I., R. E. Holzer, and E. J. Smith, "Magnetic Field Fluctuations Between 2 and 1000 Hz in the Magnetotail," submitted for presentation at the 1968 Spring AGU Meeting, Washington, D. C.

ABSTRACT: Magnetic fluctuations with energy in the 2 to 300 hz range have been observed in the magnetotail using a triaxial search coil magnetometer on OGO-I. These disturbances are most often in the form of single pulses with durations of the order of 15 seconds. They tend to occur within $\pm 3 R_e$ of the solar magnetospheric equator and in many cases are observed within the plasma sheet. Amplitude changes in the D. C. field of 5 γ or more are frequently observed at approximately the same time as the pulses.

The power associated with these events appears to be peaked in the spectral range of 20 to 60 hz. An analysis of the distribution of the time intervals between pulses indicates that the most frequently observed interval is between 15 seconds and 2 minutes. A secondary maximum in the distribution curve is found between 9 and 11 minutes.

Holzer, R. E., M. G. McLeod, and E. J. Smith, "OGO-I Search Coil Magnetometer Experiment, Preliminary Results," presented at the April 1965 AGU Meeting, Washington, D. C.

Holzer, R. E., M. G. McLeod, and E. J. Smith, "OGO-I Tri-Axial Search Coil Magnetometer Results," presented at the September 1965 AGU Meeting, Dallas, Texas.

ABSTRACT: Data obtained between October and December 1964 on OGO-I have served to identify the transition region and its boundaries with the magnetopause and the interplanetary medium.

The energy density of the fluctuating magnetic field in the frequency range from 0.1 to 1000 cps is greater and more variable in the transition region than in either adjacent region. The region near the boundary with the interplanetary medium is characterized by a spectrum with enhanced energy density at the higher frequencies. The boundary with the interplanetary medium, exhibiting sharp changes in the magnitude and direction of the dc field, was crossed repeatedly on some orbits.

Holzer, R. E., M. C. McLeod, and E. J. Smith, "Preliminary Results from the OGO-I Search Coil Magnetometer: Boundary Positions and Magnetic Noise Spectra," Preprint, *J. Geophys. Res.*, 71, No. 5, 1481-1486, March 1, 1966.

Holzer, R. E., M. G. McLeod, C. Russell, and E. J. Smith, "The Position and Structure of the Magnetopause and Shock Front," presented at the Inter-Union Symposium on Solar-Terrestrial Physics, Aug.-Sept. 1966 at Belgrade, Yugoslavia.

ABSTRACT: The Eccentric Orbiting Geophysical Observatory (OGO-I) has crossed the magnetopause while the sun-earth-probe angle was less than 120 degrees and the shock front for angles less than 90 degrees. The search coil magnetometer on OGO-I has provided high time resolution data for 20 months on the position and magnetic structure of these boundaries. The observations provide evidence of both long- and short-term changes in their position. The short-term position changes indicated by multiple boundary crossings lead to estimates of boundary velocity and thickness. Precursor waves are frequently found in the interplanetary medium in advance of the shock front. There is marked enhancement of high frequency magnetic fluctuations just inside of the shock front, close to the magnetopause in the magnetosheath, and in well defined regions inside the magnetosheath.

Holzer, R. E., and E. J. Smith, "Magnetic Fluctuations Related to Magnetopause Boundary Motions," submitted for presentation at the 1968 Spring AGU Meeting, Washington, D. C.

ABSTRACT: The OGO-I search coil magnetometer data have been analyzed for magnetically quiet intervals when multiple magnetopause crossings occurred. In these cases periodicities of the order of a few minutes were found in the magnetopause motion. Examination of the magnetosheath traversal immediately following the multiple crossings revealed decreases in the D. C. magnetic field with comparable periods. Simultaneous decreases in the amplitude of the persistent broad band noise up to a few hertz were also found in the magnetosheath. Finally, examination of the data in the interplanetary medium near the bow shock showed bursts of magnetic noise at intervals which were multiples of the magnetopause period. These preliminary results suggest that magnetopause motion may lead to a periodic modulation of plasma waves already present in the magnetosheath and the interplanetary medium near the shock front, or to their periodic production.

McLeod, M. G., R. E. Holzer, C. Russell, and E. J. Smith, "OGO-I Search Coil Magnetometer Results in the Magnetosheath and its Boundaries," presented at the April 1966 AGU Meeting, Washington, D. C.

ABSTRACT: The OGO-I search coil magnetometer, designed to measure fluctuating magnetic fields between 0.01 and 1000 cps, has been in orbit since September 4, 1965, and has obtained data during a large fraction of the period in which the solar panel orientation permitted spacecraft operation. The data have been obtained between geocentric distances of 2 and 24 R_E , and between Sun-Earth-satellite angles of 30° and 120°. The satellite has traversed the magnetopause and shock front on every orbit in which the magnetometer was operating and in which the orbital parameters permitted the crossing. The high telemetry bit rate and wide band frequency response of the equipment has permitted detailed studies of the boundary crossings. The boundaries appear to be sources of magnetic fluctuations over the entire spectral range to which the magnetometer is sensitive. Some regions within the magnetosheath away from the boundaries appear to be an additional source of broad spectrum magnetic fluctuations.

McLeod, M. G., R. E. Holzer, C. T. Russell, and E. J. Smith, "Structure of the Hydromagnetic Bow Shock," presented at the September 1966 AGU Meeting, Los Angeles, California.

ABSTRACT: Previous results of the OGO-I triaxial search coil magnetometer have demonstrated that the hydromagnetic bow shock, as measured by the change in the dc magnetic field occurs within a few tens of kilometers. The high telemetry bit rate has made possible both the accurate location of the shock and the study of its structure with high time resolution. Power spectra of the magnetic oscillations show a large decrease in power at frequencies up to several hundred cps in passing from the magnetosheath to the interplanetary side of the shock. Spectra taken across the boundary show an enhancement of power in the neighborhood of 2 cps over the power spectra within the transition region. Waves with frequencies in the range of 1 to 5 cycles/sec, originating at the shock front, are observed to extend considerable distances into the interplanetary medium.

McLeod, M. G., C. T. Russell, R. E. Holzer, and E. J. Smith, "Magnetic Fluctuations in the Vicinity of the Earth's Bow Shock Observed on OGO-I and OGO-III," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 169, Mar. 1967.

ABSTRACT: Search coil magnetometers on OGO-I and OGO-III have measured the magnetic fluctuations at frequencies less than 1000 hz at a number of bow shock crossings. Within the shock transition and in the magnetosheath immediately behind the shock, frequencies up to several hundred hz are observed. Bursts of energy at frequencies of 100 hz or more are found in relatively sharply bounded regions behind the shock. Precursor waves at frequencies from one to several hz extend from the shock into the interplanetary medium. Multiple crossings of the shock are observed on most orbits, indicating that the shock is constantly in motion.

McLeod, M. G., R. E. Holzer, and E. J. Smith, "Spectra, Direction of Propagation, and Polarization of Waves in the Magnetosheath in the Frequency Range from .01 to 140 Hz," submitted for presentation at the 1968 Spring AGU Meeting, Washington, D. C.

ABSTRACT: Magnetic fluctuations in the magnetosheath with frequency components above .01 hz have been measured by triaxial search coil magnetometers on OGO-I and OGO-III. The three components of the ambient field variations were digitally sampled at three telemetry rates corresponding to upper Nyquist frequencies of 140, 17.4, and 2.2 hz. Fluctuations in the frequency range from 14 to 140 hz often take the form of fairly monochromatic signals lasting a few tenths of a second, sometimes reaching amplitudes of 1 gamma. Fluctuations at lower frequencies do not seem to have this monochromatic character. Propagation direction, relative to the magnetic field and the magnetosheath boundaries, and signal polarization as determined by power spectra and cross spectra, will be discussed.

Olson, J. V., M. G. McLeod, R. E. Holzer, and E. J. Smith, "High Frequency Magnetic Fluctuations Associated with the Earth's Bow Shock," submitted for presentation at the 1968 Spring AGU Meeting, Washington, D. C.

ABSTRACT: Magnetic noise associated with the earth's bow shock, in the frequency range 0.5 hz to 300 hz, has been detected with triaxial search coil magnetometers on OGO-I and OGO-III. Noise power spectra obtained throughout the shock front show a continuous spectrum of noise up to at least 10 hz. The character of the spectrum depends upon the location of the data sample within the shock. In addition to the continuous spectrum, bursts of noise in the frequency range 10 hz to 300 hz are also detected at the front. Several shock crossings were monitored at high data rates and provide alias-free waveform information up to about 100 hz. These records show the bursts of high frequencies to have amplitudes in the range 0.01γ to 0.1γ and to be circularly polarized.

Russell, C. T., R. E. Holzer, M. G. McLeod, and E. J. Smith, "Magnetic Fluctuations in the Magnetosphere in the Frequency Range from 30 to 1000 cps," presented at the September 1966 AGU Meeting, Los Angeles, California.

ABSTRACT: The OGO-I triaxial search coil magnetometer was designed to measure frequencies from 0.01 to 1000 cps on a stabilized platform in the magnetosphere, magnetosheath, and interplanetary medium. The unscheduled spin of the satellite has prevented the examination of the frequency range below 1 cps throughout most of the magnetosphere. It has been possible, however, to study the higher frequencies at geocentric distances greater than some $2 R_E$, the approximate position of

perigee. Signals within the magnetosphere are observed in a relatively broad spectral band rarely extending as low as 10 cps and with maximum energy at 300 cps or higher. The signals seem to be of two types. The first type, usually found between $L = 2$ and $L = 7$, has a gradual rise and fall and exhibits some structure as the satellite passes through this region. The amplitude, location, and extent of the signals are variable. The second type is more burst-like, that is, short-lived and very irregular. It occurs randomly in the region from about $L = 5$ out to the magnetopause. The characteristics of these bursts will be discussed.

Russell, C. T., and K. I. Brody, "Some Remarks on the Position and Shape of the Neutral Sheet," *Letters, J. Geophys. Res.*, 72, 6104-6106, 1967.

Smith, E. J., R. E. Holzer, M. G. McLeod, and C. T. Russell, "Magnetic Noise in the Magnetosheath in the Frequency Range 3-300 Hz," *J. Geophys. Res.*, 72, No. 19, 4803-4813, Oct. 1967.

ABSTRACT: Preliminary results are presented concerning rapid magnetic field variations (3-300 Hz) observed in the magnetosheath by the OGO-I search coil magnetometer spectrum analyzer. Broad-band signals are continuously present in the magnetosheath at these frequencies that are relatively intense and highly variable on a time scale of tens of seconds. Power spectral density estimates for several representative intervals lead to $B(f) \approx 1/f^3$ (gamma)² Hz⁻¹. This result extends previous estimates for the fluctuating magnetic fields in the magnetosheath up to 300 Hz and reveals an apparent change in the frequency dependence of the spectrum somewhere between 0.1 and 1 Hz. The observations are discussed in terms of the two transverse modes of plasma wave propagation that exist at frequencies below the electron gyrofrequency. Arguments are presented suggesting that some high-frequency bursts seen in interplanetary space just outside the bow shock are actually precursor waves propagating upstream against the solar wind.

Smith, E. J., R. E. Holzer, P. J. Coleman, Jr., L. Davis, Jr., and G. S. Siscoe, "A Comparison of Simultaneous Interplanetary Magnetic Field Measurements: OGO-I and Mariner 4," presented at the Inter-Union Symposium on Solar-Terrestrial Physics, Aug.-Sept. 1966 at Belgrade, Yugoslavia.

ABSTRACT: Mariner 4, containing a vector helium magnetometer, continuously monitored the interplanetary magnetic field between the orbits of the earth and Mars. The first Orbiting Geophysical Observatory (OGO-I) had been launched previously and continued to make interplanetary magnetic field measurements, as well as measurements inside the earth's magnetosheath and magnetosphere, using a search coil magnetometer. Simultaneous interplanetary field measurements are available during the intervals from November 28 to December 16, 1964 and from March 8 to May 4, 1965 (OGO-I was inoperative during the intervening period). During the first interval the separation between the two spacecraft increased from $\sim 1/3$ to 5 million km, and during the second interval from 46 to 112 million km. In terms of heliocentric distances these intervals provide simultaneous measurements with both spacecraft near 1 A. U. and with OGO-I at ~ 1 A. U. as Mariner 4 travelled from 1.2 to 1.4 A. U. An investigation of the simultaneity of time variations in the interplanetary field to establish apparent velocities of propagation and the representative scale sizes of interplanetary disturbances will be reported.

Smith, E. J., R. E. Holzer, M. G. McLeod, and C. T. Russell, "Magnetic Field Variations from 3 to 1000 c/s Observed in the Earth's Magnetosphere, Magnetosheath, and in Interplanetary Space: OGO-I," presented at the Inter-Union Symposium on Solar-Terrestrial Physics, Aug.-Sept. 1966 at Belgrade, Yugoslavia.

ABSTRACT: The first Orbiting Geophysical Observatory (OGO-I), launched in September 1964, contained a triaxial search coil magnetometer designed to investigate naturally-occurring magnetic field variations in the frequency range from .01 to 1000 c/s. A survey of the higher frequency components from 3 to 1000 c/s was carried out using a multichannel spectrum analyzer. The OGO-I orbit with apogee at ~ 24 earth radii and the one-year lifetime of the satellite allowed the survey of extra-ionospheric fields to be carried out inside the magnetosphere and in interplanetary space as well as in the transition region, or magnetosheath, between them. An analysis of the signals seen in these three regions, including their field strengths and frequency spectra and their dependence on pertinent parameters, will be presented.

Smith, E. J., R. E. Holzer, M. G. McLeod, and C. T. Russell, "Magnetic Noise below 1000 Hz Observed in the Magnetosheath by OGO-I and OGO-III," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 183, Mar. 1967.

ABSTRACT: Search Coil magnetometers on OGO-I and OGO-III, launched in September 1964 and June 1966, respectively, into eccentric orbits with apogees beyond $20 R_E$, have detected rapid magnetic variations in the magnetosheath, with frequency components extending up to 1000 Hz. These measurements are of interest because they may help clarify the dynamic physical processes occurring in the magnetosheath, as well as at the shock front and magnetopause, and may contribute to understanding extremely low-frequency wave propagation in plasmas. Although strongest at the magnetopause and bow shock, the magnetic noise is a persistent feature of the magnetosheath. The signals are nonstationary and show great variability in amplitude and frequency content. Power spectral density estimates have been made when they appear warranted by relatively stationary conditions. The long active lifetimes of both satellites and their repeated passage through the magnetosheath make it possible to study the relation between the noise properties, pertinent spatial parameters, and changing magnetic activity. The results of these investigations and a discussion of the most significant aspects of these signals will be presented.

Smith, E. J., R. E. Holzer, and M. G. McLeod, "Magnetic Measurements in the Magnetosheath at Frequencies up to 1000 Hz," submitted for presentation at the 1968 Spring AGU Meeting, Washington, D. C.

ABSTRACT: Triaxial search coil magnetometers on OGO-I and III have made copious measurements of rapid magnetic field changes in the magnetosheath at geocentric distances in excess of 20 earth radii. Naturally-occurring signals have been studied with an on-board spectrum analyzer which consists of five tuned filters logarithmically spaced between 3 and 1000 Hz. The magnetosheath has been found to contain magnetic noise at all times with strong components up to several hundred Hz.

Although reasonably well confined to the magnetosheath, noise bursts are observed sporadically just outside the bow shock. The observations are attributed to plasma waves, generated within the magnetosheath or at its boundaries, propagating in the fast, transverse electromagnetic mode at frequencies below the electron gyroresonance. The continuing analysis of these signals will be reported with emphasis on recent OGO-III results.

4911 (Heppner, Rubidium-Vapor and Fluxgate Magnetometer)

Heppner, J. P., "Preliminary Results from OGO-I," presented at the April 1965 AGU Meeting, Washington, D. C.

Heppner, J. P., "Recent Measurement of the Magnetic Field in the Outer Magnetosphere and Boundary Regions," presented at the November 1965 ESRO Colloquium on Auroral and Associated Magnetospheric Phenomena at Very High Latitudes, Stockholm, Sweden, GSFC X-612-65-490, Preprint.

ABSTRACT: Within the framework of a brief review of recent magnetic field measurements in space attention is directed to initial findings from the EGO-I (OGO-A) satellite. Two particularly important results are: (1) circularly polarized, coherent oscillations of large amplitude are found at the bow shock front discontinuity. Study of the characteristics of these oscillations should significantly advance the understanding of collisionless shock waves, and (2) during periods of general magnetic disturbance when the magnetospheric tail field intensity is high, temporary decreases in tail field intensity are found to follow the onset of auroral zone negative bays in the same local time sector. This suggests that during the peak auroral activity which accompanies the onset of negative bays, the tail field in the bat sector partially collapses, or relaxes, from its highly stressed state.

An abnormal distortion of the outer magnetosphere on the day side of the earth coincides with the occurrence of an auroral zone positive bay near the same meridian. These correlations make it evident that a common mechanism is responsible for major changes in the outer magnetospheric field and the magnetic bays accompanying aurora.

Heppner, J. P., "Observations Implying $\beta \geq 1$ within the Magnetosphere near the Twilight Meridians," presented at the Inter-Union Symposium on Solar-Terrestrial Physics, Aug.-Sept. 1966, at Belgrade, Yugoslavia.

ABSTRACT: Magnetic field intensities as measured by OGO-A outside the magnetosphere but within the transition region are occasionally greater than the field intensities observed on the same orbit within the magnetosphere near its boundary. When such occurrences are of short duration or isolated by time and/or distance from the magnetosphere, interpretations are questionable. However, two cases of strong, persistent transition region fields have appeared whose characteristics and correlation with surface magnetic activity strongly suggest: (1) that at these times within the adjoining magnetospheric region $\beta = P/(8^2/8\pi) \geq 1$, and (2) that this condition may be important in the generation of magnetic disturbance observed at the earth's surface.

The two cases occur, respectively, near opposite twilight zones with magnetopause crossings near 18:00 and 04:30 hours local time. In both cases (a) the satellite is inbound near the equator, (b) the transition region field intensity for several hours prior to crossing the boundary is significantly greater than the magnetospheric field intensity observed for two hours after crossing the boundary, (c) the overall period of interest is one in which there is considerable bay activity in the auroral zone (3-hour $k_p = 3$ to 4), and (d) the level of short-period (e.g., 1 to 20 minute) magnetic field fluctuations at auroral latitudes is much greater than average at all longitudes. It is probably also significant that the case near evening twilight coincides with an exceptionally strong and wide-spread positive bay disturbance centered near the same meridian.

Although speculative at this stage in the data analysis it appears probable that the condition $\beta > 1$ may frequently exist inside the magnetosphere adjacent to the magnetopause on the night side of the earth where the equatorial zone of low field intensity within the tail intersects the magnetopause surface. At these times and locations the magnetopause is likely to be unstable and exchange of magnetospheric and transition region plasma may result. An important subsequent question is whether or not this exchange has a preferred direction which would result in a net entry of solar wind particles.

Heppner, J. P., "OGO-A Measurements of Magnetic Field Variations within the Geomagnetic Cavity between 4 and 24.5 R_e ," presented at the Inter-Union Symposium on Solar-Terrestrial Physics, Aug.-Sept. 1966, at Belgrade, Yugoslavia.

ABSTRACT: The spatial distribution of the difference, ΔB , between the measured magnetic field and the extrapolated earth's main field has been mapped over a 360° range of sun-earth-probe angles at distances greater than 4 R_e and extending to 24.5 R_e in the geomagnetic tail. The change in orbit inclination with time during the 20 months operation (as of May 1966) is such that measurements are received at latitudes as high as 58° in selected regions in addition to more comprehensive coverage in equatorial and low-latitude regions. On the dayside of the earth average differences are explained reasonably well as the combined effect of cavity compression and an equatorial ring current source having its maxima below 4 R_e . On the nightside one must also postulate the existence of an equatorial ring current source below 4 R_e to explain observations at 4 R_e . Between 5 and 14 R_e on the nightside the field near the geomagnetic equator is typically weaker than the extrapolated earth's main field. Zero field intensities are not, however, observed within this range or at greater distances. The tail field outside this equatorial region tends to increase in magnitude with increasing latitude. Exceptionally strong fields (e.g., $\Delta \beta > 40 \gamma$) are found between 30° and 55° geomagnetic latitude at distances of roughly 5 to 9 R_e . This may be the consequence of outward plasma pressures from the equatorial weak field region.

During magnetic disturbances it is apparent that the spatial distribution of field differences on the nightside is not markedly different. Instead one finds a general enhancement of the prevailing features such that $|\Delta B|$ increases with $|\Delta B|$ keeping the same sign. However, superimposed on this average behavior there are large fluctuations at low latitudes. Particular importance is attached to sudden changes on the nightside which correlate with the onset of negative bays in the auroral zone. The existence of definitive correlation is dependent on the satellite being near the meridian of the onset point at the earth's surface. This feature, other morphological arguments and the fact that the change at the satellite occurs several or more minutes after the change in the auroral zone, suggest that the instability triggering the negative bay onset originates well within the closed magnetosphere or in the auroral ionosphere. The proposition is put forth that the sudden onset results from

ionospheric short-circuiting of the electrical potential field already in existence and driving the auroral zone currents prior to the onset.

Heppner, J. P., M. Sugiura, B. G. Ledley, T. L. Skillman, and M. J. Campbell, "Results from OGO-A (EGO) Magnetic Field Measurements at Distances of 4 to 24.5 R_E ," presented at the April 1966 AGU Meeting, Washington, D. C.

ABSTRACT: Between September 1964 and December 1965 a great quantity of magnetic field data has been obtained from the OGO-A satellite over a 360° range of Sun-Earth satellite angles. Many of the handicaps in data analysis resulting directly or indirectly from failure of boom deployment and spacecraft stabilization have been overcome, and good quality data have been obtained for study of a number of phenomena. Several important findings are: (1) Circularly polarized, coherent oscillations of large amplitude are found directly at the bow shock front discontinuity formed with the solar wind (see companion paper). (2) Field intensities in the magnetospheric tail are found to decrease temporarily following the onset of a negative magnetic bay in the auroral zone, when the negative bay occurs near the local time meridian of the satellite, suggesting that during the peak auroral activity, which accompanies and follows the negative bay onset, the tail field in the bay sector partly collapses, or relaxes, from its high stressed state. (3) The occurrence of auroral zone bay on the day side is accompanied by field distortion along the corresponding L shell and at greater distances. Models for these distortions have not been obvious, and the possibility of current flow along field lines needs to be studied. (4) Long-period hydromagnetic waves with periods of 4 to 15 minutes are frequently observed beyond roughly $8 R_E$. (5) Some crossings of the magnetosphere boundary show a deviation of the field direction prior to encountering transition region characteristics. In these cases, the term 'boundary layer' may be appropriate, but this feature requires further study. (6) The transition region exhibits different characteristics at different times, ranging from apparent field stability to apparent chaotic variations.

Heppner, J. P., M. Sugiura, B. G. Ledley, and T. L. Skillman, " $\beta \simeq 1$ in the Outer Magnetosphere near the Dawn Meridian from Magnetic Field Measurements," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 175, Mar. 1967.

ABSTRACT: On inbound passes of OGO-A crossing the magnetopause between local times of 4h 30m and 6h 30m the satellite was within 15° of the geomagnetic equator between 20 and 10 R_E for most orbits during May and June 1965. Along these passes the transition region magnetic field B_t near the magnetopause is characteristically $\geq B_m$, the magnetic field intensity within the adjacent magnetosphere near the magnetopause. To maintain pressure balance across the magnetopause, $P_m + B_m^2/8\pi = P_t + B_t^2/8\pi$, the magnetospheric plasma pressure P_m must thus be $\geq B_m^2/8\pi$. For example, for $B_t \geq \sqrt{2}B_m$, $\beta_m \geq 1$ even if $P_t = 0$. Related observations along these passes include the following: (1) Between 11 R_E and the magnetopause the average field gradient with radial distance is essentially 0. This implies $\beta_m \simeq 1$ over a broad region. (2) In a number of cases there is very little contrast between magnetospheric and transition region field behavior, and magnetopause identification is uncertain using only the field data. (3) During a disturbed period, $B_t \geq \sqrt{2}B_r$ is observed, suggesting $\beta_m > 1$. (4) The data sampling and latitude versus distance orbit characteristics near the dusk meridian do not permit as comprehensive a view as near dawn; however, during one disturbed period a similar behavior was observed. (5) On outbound passes at magnetic latitudes $25^\circ - 45^\circ$ near the dawn meridian, these characteristics are not observed. These observations have a variety of implications related to magnetopause stability, plasma entry, tail formation, and the generation of secondary shocks within the transition region.

Heppner, J. P., M. Sugiura, T. L. Skillman, B. G. Ledley, and M. Campbell, "OGO-A Magnetic Field Observations," GSFC X-612-67-150, *J. Geophys. Res.*, 72, No. 21, 5417-5471, Nov. 1, 1967.

ABSTRACT: This paper summarizes the new findings that have come from the initial study of the OGO-A fluxgate magnetometer measurements between 4 and 24.5 R_E (earth radii). These include the following: (a) A model magnetic field profile of the cross-sectional structure of the bow shock is derived in terms of the sharpness of the interface, the rise time, and the total time interval occupied by a field pile-up at the shock. Using a simple model to derive the velocity of shock movements, the times are converted to three thickness dimensions roughly of the order <20, 70, and 250 km, which

emphasizes the need for strict definition of the meaning of 'thickness' in collisionless shock theories. (b) Superimposed on the average shock structure, (a) above, two classes of field oscillations are frequently observed: coherent circularly polarized waves with frequencies typically between 0.5 and 1.5 cps in the satellite reference frame, and higher frequency fluctuations, > 7 cps, which are unresolved by the measurements and whose identity is not known. The coherent oscillation is identified as being in the whistler mode, exists in the form of wave packets, and usually shows a sharp upper frequency cut-off in power spectrum analysis. (c) A series of bow shock crossings during the main phase of the April 18, 1965, magnetic storm occur at an abnormally large distance from the earth principally as a consequence of the strong, 20–27 γ , interplanetary field that lowers the Alfvén Mach number to 1.5. The transition region magnetic field adjacent to the shock interface is exceptionally stable in contrast to a number of theoretical predictions and the typical shocks observed at high Mach numbers. (d) The magnetopause in the sunward hemisphere is most typically observed as a smooth transition over a dimension comparable to the ion cyclotron radius. (e) The correlation of negative bay onsets in the auroral belt with OGO-A observations on the night side of the earth supports more general morphological arguments that the onset originates within the closed magnetosphere or auroral ionosphere and is not dependent on being triggered by a sudden change in the solar wind plasma or field. The view is advanced that the onset results from short-circuiting effects in the ionosphere. (f) At middle latitudes between 5 and 10 R_E near the midnight time sector the total field intensity is found to be considerably stronger than predicted by existing field models. This is believed to be caused by high plasma pressures near the equator at similar distances in the same time sector. (g) Near the magnetopause within the local time sector 4h 30m–6h 30m and geomagnetic latitudes $\pm 15^\circ$ the magnetospheric field intensity is generally found to be $\leq B_T$, the field intensity in the adjacent transition region. This condition and the behavior of the field gradient within the magnetosphere leads to the conclusion that a $\beta \geq 1$ condition must persist over this sector of the outer magnetosphere beyond 11 R_E . The consequences of the magnetopause being a boundary between two high β regions are noted in terms of boundary instability, plasma entry, and the possible existence of secondary shocks in the transition region. A similar, but not identical, condition may exist in the evening twilight local time sector.

Skillman, T. L., "Temporal and Spatial Variations in the Geometry of Magnetopause and Bow Shock Boundary Surfaces from OGO-A Magnetic Field Measurements," presented at the Inter-Union Symposium on Solar-Terrestrial Physics, Aug.–Sept. 1966, at Belgrade, Yugoslavia.

ABSTRACT: The geometry of the magnetopause and bow shock surfaces within $\pm 100^\circ$ and $\pm 135^\circ$ respectively, of the sun-earth line has been mapped for two consecutive years by OGO-A magnetometers. Statistically the boundary locations agree well with theoretical prediction when the aberration caused by the earth's orbital motion around the sun is taken into account. However, at any arbitrary time the location of either surface may be found displaced as much as several earth radii from the average position.

Multiple crossings of the bow shock are a prevailing characteristic of the OGO-A observations. Ten to twenty or more crossings during a single satellite pass are not uncommon. Single crossings are rare by comparison. These observations suggest several alternative explanations ranging from continuous variation of the bulk flux in the solar wind to more localized response of the surface to small scale inhomogeneities or filaments in the solar wind. Multiple crossings of the magnetosphere boundary occur less frequently. On the sunward side this is in part a consequence of the greater satellite velocity at magnetopause distances.

The futility of using boundary locations as given by satellite crossings to seek direct correlation of k_p indices with solar wind flux is apparent.

Recognition of the variability of crossing distances within several hours of time makes it obvious that a 3-hour index is not adequate for this correlation.

Sugiura, M., "The Structure of the Magnetosphere Boundary and of the Bow Shock as Observed by the OGO-A Satellite," presented at the Inter-Union Symposium on Solar-Terrestrial Physics, Aug.–Sept. 1966, at Belgrade, Yugoslavia.

ABSTRACT: The thickness of the magnetosphere boundary is found to be of the order of the effective Larmor radius of the ion. The electrons in the transition region are therefore sufficiently

thermalized to short-circuit the electric field in the boundary layer. Within this boundary layer the magnetic field varies slowly from the field inside the magnetosphere to that in the transition region.

The thickness of the bow shock is much less than that of the magnetosphere boundary layer. Quasi-periodic waves of frequency roughly 1 c/s are often observed in the immediate vicinity of the shock, and these waves are found to diminish both in the frequency of occurrence and in their amplitude with increasing distance from the shock wave. Ahead of the shock, i.e., in the interplanetary medium, these waves show a remarkable characteristic of a frequency cutoff near 1.5 to 3 c/s. Behind the shock the power spectral density is greatly enhanced, and no frequency cutoff is observed below 7 c/s which is the Nyquist frequency of the present analysis. The frequencies quoted above are defined in a reference frame fixed to the satellite. When transformed to a frame of reference stationary to the solar wind plasma the frequency cutoff in the solar wind medium ahead of the shock can be interpreted as the cutoff for plasma waves at the electron cyclotron frequency in the solar wind. Behind the shock the plasma flow is irregular, and no sharply defined frequency cutoff is expected. It is proposed that waves with frequencies near 1 c/s are a main constituent of the shock wave itself and that they represent an important energy source for heating the electrons in the shock wave.

Sugiura, M., J. P. Heppner, B. G. Ledley, T. L. Skillman, and M. J. Campbell, "The Magnetosphere Bow Shock as Observed by OGO-A," presented at the April 1966 AGU Meeting, Washington, D. C.

ABSTRACT: Several new aspects regarding the structure of the magnetosphere bow shock and the transition region are revealed by the rapid sampling in the OGO-A magnetic field measurements. To describe the observed features unambiguously a plane of discontinuity is defined that separates interplanetary space from the shocked region. In several examples examined, coherent waves of large amplitudes are observed in the vicinity of the discontinuity on its downstream side. The typical frequency of these coherent waves is roughly 1 cps, and their polarization is circular. In terms of wave mode, these waves fall in the regime of the whistler mode. Power spectrum analyses for the region behind the discontinuity (i.e., on the downstream side) indicate that the power spectral density is increased by a larger factor in a frequency range containing the above characteristic frequency, implying existence of incoherent waves. Coherent waves of comparable frequencies with those of coherent waves observed behind the discontinuity are sometimes found in front of the discontinuity. This is interpreted as an indication of leakage in the upstream direction of waves with group velocity exceeding the plasma streaming velocity in interplanetary space.

4912 (Sagaly, Spherical Ion and Electron Trap)

Sagaly, R., and M. Smiddy, "Density Flux and Energy Distribution of Charged Particles in the Energy Range 0 to 1 Kev: OGO-I," presented at the April 1965 AGU Meeting, Washington, D. C.

Sagaly, R. C., and M. Smiddy, "Results of Charged Particle Measurements in the Energy Range 0 to 1000 ev, OGO-A," presented at the May 1965 Space Science Symposium, COSPAR, Mar del Plata, Argentina, also *Space Research VI*.

ABSTRACT: Results obtained during the first three months of operation of two spherical electrostatic analyzers flown on the OGO-A satellite launched Sept. 5, 1964 are presented. One instrument was designed to measure the density, flux and energy distribution of thermal (0 to 25 electron volts) and non-thermal (20 to 1000 electron volts) electrons in sequence at 12 minute intervals. The second analyzer measured the same properties of positive ions.

Typically the densities of thermal ions and electrons decrease rapidly with altitude between 4 and 6.5 earth radii and then decrease more gradually to a value of approximately $10 \text{ particles cm}^{-3}$ at 24 earth radii. At altitudes above 30,000 km the average energy of positive ions is found to be 5 ev, and is 7.5 ev for the electrons; both increase gradually with distance from the earth.

There is found, however, a significant number of particles with energies up to 22 ev.

The positive ion flux in the energy range 26 to 1000 ev is found to vary between 10^6 and $10^8 \text{ cm}^{-2} \text{ sec}^{-1}$; the electron flux varies between 10^7 and $10^9 \text{ cm}^{-2} \text{ sec}^{-1}$. The average ion energy in the higher energy mode is about 350 ev and is 1.5 times larger than the average electron energy.

The variations with radial distance and time of charged particle flux, density and energy are presented and discussed. The results are also correlated with solar and magnetic activity.

Smith, L. G., "Ionospheric Experiment for the Eccentric Geophysical Observatory," Nov. 15, 1961. N62-13243.

ABSTRACT: An instrument which combines the spherical ion trap for positive ion analysis with the Langmuir probe technique for electrons is proposed for inclusion in the first Eccentric Geophysical Observatory. The instrument is basically the one used by Gringauz on Sputnik III, but with two important improvements. The first is the addition of a second grid to reduce photoemission current from the collector and improve the minimum measurable ion density by a factor of 20. The second is the use of a modulated sweep with advantages in instrument stability and data presentation. Author

4913 (Whipple, Planar Ion and Electron Trap)

Parker, L. W., and E. C. Whipple, Jr., "Theory of a Satellite Electrostatic Probe," *Annals of Physics*, 44, 126-161, 1967.

ABSTRACT: A theoretical study is presented of the properties of a circular planar electrostatic probe, flush-mounted in the skin of a satellite. This geometry results in a two-dimensional potential distribution. The current-voltage characteristics of the external aperture grid and of an internal repelling collector (for attractive aperture-grid potentials) are investigated by means of several techniques involving detailed analysis of particle trajectories. An approximate theory is found to give useful insight into the properties of the probe. More exact numerical calculations are made by following trajectories in the field of the probe when the Debye length is infinite (Laplace field) and when the Debye length is finite (Poisson field). The Poisson field is computed by an iterative technique in which the charge densities in the Poisson equation are evaluated by summing charge contributions over trajectories. It is found that when the internal collector is repelling with respect to the plasma, its current-voltage characteristic is similar to that of a repelling probe, regardless of the fact that the external aperture grid is attractive. This has important consequences for satellite experiments.

Whipple, E. C., "Preliminary Electron Energy Spectra below 30 ev in the Magnetosphere from OGO-I," presented at the December 1964 AGU Meeting, Seattle, Washington.

ABSTRACT: Electron energy spectra below 30 ev have been obtained at geocentric distances from 8500 to 155,000 km by means of an electron trap on OGO-I. The spectra characteristically show a thermal component of a few thousand degrees temperature superimposed on a high-energy tail. As the altitude increases, the thermal contribution decreases and the high-energy contribution increases. At 155,000 km (OGO-I apogee) the temperature of the thermal component is about 50,000°K.

Whipple, E. C., and B. E. Troy, "Preliminary Ion Data from the Planar Ion-Electron Trap on OGO-I," presented at the April 1965 AGU Meeting, Washington, D. C.

ABSTRACT: Several ion density profiles between approximately 900 km and 23,000 km altitude have been computed from the ion currents measured by the experiment. The accuracy of the computed densities depends on a knowledge of the orientation of the spacecraft and on corrections for the attractive field at the experiment aperture.

The background currents due to particles of energies greater than 30 ev are shown to have good correlation with the radiation belts. Peak fluxes occur for electrons at an L value of 1.58 and for protons at an L value of 4.2.

Some densities and temperatures of thermal electrons in the solar wind have been measured. Typical values are 20/cm³ and three eV with a higher energy tail. The electron flux is nearly isotropic except for occasional enhancements that appear to be correlated with the local magnetic field rather than with the solar direction.

4914 (Hargreaves, Radio Propagation)

da Rosa, A. V., "Eccentric Geophysical Observatory Satellite S-49 with Interpretation of the Radio Beacon Experiment," Stanford University Radioscience Technical Report SEL 65-063, June 1965.

da Rosa, A. V., "Thermal Behavior of the Ionosphere and Observations of the Exosphere and the Ionosphere by Means of Distant Earth Satellites," Stanford University Radioscience Technical Report SU-SEL-65-109, Dec. 1965.

da Rosa, A. V., O. K. Garriott, F. L. Smith, III, S. C. Hall, and E. R. Schiffmacher, "Results from the Radio Beacon Experiment on the Orbiting Geophysical Observatory," presented at the October 1965 Second Symposium on Radio Astronomical and Satellite Studies of the Atmosphere, Boston, Mass.

da Rosa, A. V., O. K. Garriott, S. C. Hall, and E. R. Schiffmacher, "Ionosphere and Exosphere Observations by Means of the EGO Satellite," presented at the April 1966 Joint URSI-IEEE Spring Meeting, Washington, D. C.

Fritz, R. B., E. R. Schiffmacher, and J. K. Hargreaves, "Response of Ionospheric and Exospheric Electron Contents to a Partial Solar Eclipse," presented at the October 1967 Fall URSI Meeting, Ann Arbor, Michigan. Submitted for publication.

ABSTRACT: The partial solar eclipse on May 9th, 1967 occurred shortly after ground sunrise at Boulder, Colorado, at a time when it was possible to monitor the OGO-I radio beacon experiment. OGO was outbound at a range of approximately 10 earth radii and maintained an almost constant position in the sky. The electron contents measured by the Faraday rotation and phase path methods continued to increase during the eclipse but deviated significantly from the linear increase typical of other sunrise periods. The maximum eclipse effect on total content was reached 35 minutes after maximum obscuration (41% obscured at 300 km altitude) when the equivalent vertical content was estimated to be 3.7×10^{12} electrons/cm² (or 24%) below that of a comparable control day. The relative exospheric content exhibited only slight depletion, implying that most of the change was in the F-region rather than the exosphere.

Lawrence, R. S., E. R. Schiffmacher, R. B. Fritz, A. V. da Rosa, S. C. Hall, and O. K. Garriott, "Preliminary Results from the OGO-I Propagation Experiment," presented at the April 1965 AGU Meeting, Washington, D. C.

Obayashi, T., "Ionospheric Experiment Using the Orbiting Geophysical Observatory (OGO-A) at the Ionosphere Research Laboratory, Kyoto University," *Report of Ionosphere and Space Research in Japan*, 19, 214-224, April 1965.

ABSTRACT: Radio Propagation experiments by using the transmitted VHF waves from the Orbiting Geophysical Observatory (OGO-A) have been made during the period from September to December 1964. Ingenious methods are developed to reduce the electron density in the ionosphere and the magnetosphere from the observed Faraday fadings and differential Doppler shifts. Some provisional results of analysis are described briefly.

4915 (Taylor, Atmospheric Mass Spectrum)

Brinton, H. C., R. A. Pickett, and H. A. Taylor, Jr., "Positive Ion Composition and Concentration Data Obtained from the OGO-A Satellite," presented at the April 1966 AGU Meeting, Washington, D. C.

ABSTRACT: Ion composition and concentration data obtained from the positive ion spectrometer experiment aboard the OGO-A satellite during the period December 1964 to August 1965 are presented. The measured distributions of thermal hydrogen and helium ions extend from 3,000 to 30,000 km, the He⁺ concentration being 1% of the H⁺ over most of the altitude range. The density of H⁺ is approximately 10^3 ions/cm³ at 3,000 km and decreases at higher altitudes in a manner suggesting that ionic diffusion is controlled by the geomagnetic field. Preliminary comparisons between these data and the results previously reported from this experiment for the period September

to December 1964 indicate a lessening in the dependence of the altitude of sharp ion density gradient on the magnetic activity index. The apparent change in this relationship may be attributable to a mixing of local time and geomagnetic effects.

Brinton, H. C., R. A. Pickett, and H. A. Taylor, Jr., "Thermal Ion Structure of the Plasmasphere," submitted to *Planet. Space Sci.*, 1968.

ABSTRACT: The distribution of thermal positive ions of hydrogen and helium in the magnetosphere has been determined from OGO-I ion mass spectrometer measurements made between September 23, 1964 and June 17, 1965. The distribution is strongly controlled by the geomagnetic field, its chief feature being a region of toroidal form, the plasmasphere, bounded approximately by the $L = 4.5$ shell within which the ion concentration decreases slowly with increasing altitude from an initial value of 3×10^3 ions/cm³ at 2000 km. At the boundary of this region, which is compressed during periods of high magnetic activity, a sharp decrease in the ion concentration by a factor of ten or more for an altitude increase of less than one earth radius is observed, leading to a concentration beyond the boundary of less than 10^2 ions/cm³. An apparent diurnal expansion in the plasma distribution is centered at 2000 hours. Over most of the altitude range within the plasmasphere the concentrations of H⁺ and He⁺ are observed in a constant ratio of 300/1, indicating departure from simple diffusive equilibrium. Measurements made by an identical spectrometer on OGO-III generally confirm these properties of the plasmasphere; significant correlation also exists with whistler observations of the magnetospheric thermal electron distribution. Correlation of latitude variations of ion composition measured by the OGO-II spectrometer with the high altitude distributions obtained by OGO's I and III indicate possible ionosphere-magnetosphere coupling.

Taylor, H. A., H. C. Brinton, and C. R. Smith, "Preliminary Results from Measurements of Hydrogen and Helium Ions below 50,000 Km," presented at the April 1965 AGU Meeting, Washington, D. C.

Taylor, H. A., H. C. Brinton, and C. R. Smith, "Positive Ion Composition in the Magneto-Ionosphere Obtained from the OGO-A Satellite," *J. Geophys. Res.*, 70, 5769-5781, December 1965.

ABSTRACT: First results from the OGO-A positive ion spectrometer experiment are presented for the period Sept. 23 through Dec. 10, 1964. Thermal hydrogen and helium ion distributions extend from the lowest observations at 1500 km to an altitude of 30,000 km. The density obtained for H⁺ at 2000 km is of the order 10^3 ions cm⁻³, and the He⁺ concentration is 1% of H⁺ over most of the altitude range. Whereas the concentration and distribution of H⁺ observed at the lower altitudes is in general agreement with theoretical models, the upper altitude profiles show significant departure from predictions based on diffusive equilibrium theory. Evidence is presented indicating that diffusion of ions is controlled by the geomagnetic field and that the ions are distributed in a beltlike region which exhibits a sharp gradient resulting in a "plateau" at its outer boundary, which is characterized by a reduction in both the H⁺ and He⁺ concentrations by a factor of 10 or more. The ion belt is observed to expand and contract over an altitude range of 8000 to 30,000 km in an inverse relationship with the magnetic activity index A_p . There is significant correlation between these results and the knee whistler observations as well as with high-altitude ionization gradients observed from other satellites. Although the data provide some indication of a direct coupling between the lower and upper ionosphere, more data will be required to describe this relationship adequately.

Taylor, H. A., H. C. Brinton, and M. W. Pharo, III, "Compression of the Plasmasphere During Geomagnetically Disturbed Periods," GSFC X-621-67-559, Preprint. Also to be published in *J. Geophys. Res.*, 73, 1968.

ABSTRACT: Direct measurements of the thermal positive ions of hydrogen and helium have been obtained from positive ion mass spectrometers aboard the Orbiting Geophysical Observatories I and III. Observations made during 1965 and 1966 show distributions of H⁺ and He⁺ extending to altitudes as great as 40,000 kilometers, corresponding to a magnetospheric coordinate of $L = 8$. Typical H⁺ profiles exhibit a comparatively gradual decrease in concentration with height within the plasmasphere. The outer boundary of the plasmasphere, however, is characterized by an abrupt

decrease in the ion concentration. This boundary or plasmopause, defined by the reduction of H^+ concentration to 5×10^0 ions/cm³ or less, is often quite sharp, with decreases in ion concentration of as much as an order of magnitude occurring within 250 kilometers of 0.1L. The position of the plasmopause is observed to move inward and outward from the earth in an inverse correlation with the planetary magnetic activity index K_p , indicating significant large scale expansion and contraction of the plasmasphere during periods of agitated magnetospheric conditions. The magnetosphere was generally disturbed during the period 7-9 July 1966, with importance 2 solar flares occurring on the 7th, 8th, and 9th, and a sudden commencement of an extensive magnetic storm at 21:03 UT on 8 July. At 11:56 UT on 9 July, the H^+ boundary was observed to be unusually low, at 3.3L and at a local time of 00:45 hours. This observation is in sharp contrast with measurements of the plasmopause on both preceding and succeeding orbits, when in the absence of flares and magnetic disturbance the plasmasphere was observed to expand to L values as high as 6, at nearly the same local time. These results are consistent with measurements during a lesser storm which occurred on 25 June 1966, and with earlier observations of the disturbed plasmasphere obtained from the OGO-I experiment. The apparent correlation between measurements of the hydrogen ion boundary and the "knee" whistler evidence of the plasmopause suggests that the mechanism responsible for the depletion of the ionization is effective along the lines of the magnetic field, extending well into the earth's inner atmosphere, to 1000 kilometers and below.

Taylor, H. A. Jr., H. C. Brinton, and M. W. Pharo, III, "Evidence of Contraction of the Earth's Thermal Plasmasphere Subsequent to the Solar Flare Events of 7 and 9 July 1966," presented at the COSPAR Meeting, London, July 1967. To be published in the Proton Flare Project issue of IQSY Annals.

ABSTRACT: Direct measurements of thermal H^+ and He^+ in the magnetosphere have been obtained from ion mass spectrometers on Orbiting Geophysical Observatories I and III. Typical H^+ profiles exhibit a gradual decrease in concentration with altitude within the plasmasphere, while the outer boundary of the plasmasphere is characterized by an abrupt decrease in concentration to 5 ions/cm³ or less. This boundary, the plasmopause, is observed to move inward and outward in an inverse correlation with the magnetic activity index K_p . The magnetosphere was disturbed during the solar flare period 7-9 July 1966, and on 9 July the plasmopause was observed to be unusually low, at $L = 3.3$. This observation contrasted with measurements of the plasmopause on both preceding and succeeding orbits, when in the absence of flares and magnetic disturbance the H^+ boundary was observed to expand to L values as high as 6. These measurements correlate well with "knee" whistler observations of the plasmopause.

4916 (Bohn, Interplanetary Dust Particles)

Alexander, W. M., O. E. Berg, C. W. McCracken, C. S. Nilsson, and L. Secretan, "Measured Speeds of Interplanetary Dust Particles," presented at the April 1965 AGU Meeting, Washington, D. C.

Bohn, J. L., W. M. Alexander, and W. F. Simmons, "Results of Studies of Thermal Gradient Effects on Ceramic Transducer Sensors Used in Cosmic Dust Experiments," presented at the 10th COSPAR Meeting, London, 1967.

ABSTRACT: An extensive study of thermal gradient and temperature effects on ceramic transducer sensors used in cosmic dust experiments on rockets, satellites and deep space probes has been conducted. The transducers used in the tests were sensors from experiments on Explorer I, Pioneer I, Vanguard III, Explorer VIII, Mariner II, Mariner IV, OGO's I, II and III, Surveyor Lander and AIMP-E spacecraft. The sensors were subjected to temperatures over a range of $-20^\circ\text{C} \leq t \leq +46^\circ\text{C}$, and both positive and negative thermal gradients (t_{gd}) over a range of $0.01^\circ\text{C/m} \leq t_{gd} \leq 2.2^\circ\text{C/m}$. More than 350 transducer thermal cycles were conducted using the various transducer types of the above space experiments and simulating the different thermal conditions experienced by the sensors. The data from these tests show that thermal noise from the transducers has not been a major source of false data from the above experiments. The results of these new studies are discussed and interpreted with respect to the data from all previous dust particle experiments and other thermal studies.

Bohn, J. L., W. M. Alexander, and A. Wever, "Results of Recent Microparticle Hypervelocity Impact Studies Related to Sensors of Cosmic Dust Experiments," presented at the 10th COSPAR Meeting, London, 1967.

ABSTRACT: Studies have recently been conducted concerning the response of sensors used in cosmic dust experiments to hypervelocity impacts of microparticles. The physical and dynamic characteristics of the microparticles used in the studies were:

- (1) mass - $10^{-13} \text{ gm} \leq m \leq 10^{-11} \text{ gm}$,
- (2) density - $2 \text{ gm/cc} \leq \rho \leq 8 \text{ gm/cc}$, and
- (3) velocity - $2 \text{ km/sec} \leq v \leq 10 \text{ km/sec}$.

With the exception of the penetration sensors, the major portion of the data from the dust particle experiments on satellites and space probes has come from microphone sensors. Previously, these data were interpreted in terms of low velocity calibrations which showed the sensor signals to be primarily related to the momentum of the impacting particle. The hypervelocity experiments show that the sensor response is related in a non-linear fashion to the velocity of the impacting microparticle. The results of these experiments are used to present a new interpretation of the data from previous satellite experiments, in particular those on Explorer I, Explorer VIII and Vanguard III which have provided more than 90% of the data from experiments using microphone sensors.

Nilsson, C. S., W. M. Alexander, C. W. McCracken, O. E. Berg, and L. Secretan, "Measured Velocities of Interplanetary Dust Particles," *Nature*, 208, 673, 1965.

Nilsson, C. S., and W. M. Alexander, "Measured Velocities of Interplanetary Dust Particles OGO-I," Proceedings of the Symposium on Meteor Orbits and Dust, *Smithsonian Contributions to Astrophysics*, 1966.

4917 (Helliwell, VLF Noise and Propagation)

Angerami, J. J., R. L. Smith, and N. Dunckel, "Analysis of Whistlers Received by the OGO-I Satellite," presented at the April 1966 Joint URSI-IEEE Spring Meeting, Washington, D. C.

ABSTRACT: The broad band VLF receiver aboard the OGO-I satellite picks up whistlers when the spacecraft position is such that $L < 6$ and the geocentric distance is less than 5 earth radii.

Both ducted and non-ducted whistlers are received and, among the former, the ones exhibiting a true nose are especially useful for detailed study of the electron density in the magnetosphere.

Comparison of time delays of whistlers propagating to the satellite from both hemispheres (1^- and 0^+ whistlers) provides a clear-cut distinction between models for the relative electron density distribution along the field lines, supporting the diffusive equilibrium model of the plasmasphere.

Angerami, J. J., "Asymmetric Distortions of the Magnetosphere Observed by Whistlers Received by OGO-I," presented at the 1967 URSI Spring Meeting, Ottawa, Ontario, Canada, May 23-26, 1967.

ABSTRACT: Time delays and nose frequencies of fractional hop whistlers received by OGO-I on 20 October 1964 were measured. The satellite was at a geomagnetic latitude 20 degrees south, and on an L shell of about 3, near local midnight. Measurements of the time delays for short and long fractional hop whistlers were made by comparison of the satellite recordings with VLF recordings obtained simultaneously at two ground stations in the opposite hemispheres: Suffield Experimental Station (SES), in Canada, and the USNS Eltanin (ELT), in the South Pacific.

The time delays of the short fractional hop whistlers (" 0^+ " whistlers) are consistent with delays of 1 hop whistlers observed at the same time at SES.

On the other hand, the ratio of the time delay of the long fractional hop (" 1^- " whistlers) to that of the " 0^+ " was about 6% larger than the same ratio calculated using the Jensen and Cain field. The nose frequency of the " 1^- " whistlers also showed a small discrepancy, about 6% smaller than predicted. Both discrepancies are attributed to a distortion of the geomagnetic field, by effects of the solar wind and currents in the tail of the magnetosphere.

Calculations of nose frequencies and time delays using a distorted field were found in qualitative agreement with the observations. The distorted field was taken as a sum of the Jensen and Cain field, plus the cavity and tail fields proposed by Mead (1964) and Williams and Mead (1965). The tail field was located according to the results reported by Speiser and Ness (1967).

The angle between the dipole axis and the solar wind direction was at that time 14 degrees. Under more favorable conditions (solstices), this angle may be as large as 35 degrees, and under such conditions an asymmetric distortion of the field is expected. This distortion can be conveniently studied by whistlers received by OGO-I and OGO-III, if ground data collected simultaneously, with precise timing are available. The whistler method, giving an integrated measurement, is comparable to the use of drift in L shell of high energy particle fluxes, but in addition features the possibility of detecting asymmetric distortions in the field.

Angerami, J. J., and R. L. Smith, "Ducted Whistlers on OGO-I and III," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 88, Mar. 1967.

ABSTRACT: Ducted Whistlers received at OGO-I and III present frequency-time characteristics that change discretely with time, corresponding to the motion of the satellite through different ducts of field-aligned enhancements of ionization. It is therefore possible to identify the ducts traversed and measure their sizes and spacings. Whistler data collected by OGO-III on June 15, 1966, between 4.5 and 5 Earth radii near the equatorial plane in the nightside of the Earth, will be presented as evidence for several field-aligned ducts, with widths ranging between 200 and 400 km at the satellite. Although the duct theory of whistler propagation has been supported in the past by VLF data collected by ground stations, the results reported in the present paper represent the first direct evidence of ducts beyond 3 Earth radii. Within the inner ducts there is observed leakage of the higher frequency portions of whistlers traveling in outer ducts. The frequency above which the leakage is observed is approximately half the local gyrofrequency, in accord with the prediction of the ray theory of ducting. It will be shown that the time delays and nose frequencies of the ducted fractional hop whistlers are in good agreement with the calculations if the magnetic field measured at the satellite is used, rather than the Jensen and Cain field, which was about 6% higher at the time considered. Simultaneous VLF recordings at a ground station were used as reference for measurement of the actual time delays.

Carpenter, D. L., N. Dunckel, and J. Walkup, "A New Very Low Frequency Phenomenon: Whistlers Trapped Below the Protonosphere," *J. Geophys. Res.*, 69, 5009-5018, December 1964.

ABSTRACT: A new whistler phenomenon has been identified through measurements at ground stations, on an Aerobee rocket between 100 and 200 km, and on the Alouette satellite at 1000 km. The new phenomenon is called the 'subprotonospheric' or 'SP' whistler, since most of its path appears to be restricted to the region below about 1000 km. The first example of an SP whistler was reported by Barrington and Belrose. In the present report a large number of observations are summarized, and the basic characteristics of the new phenomenon are described. Experimental results are presented which suggest that the whistler ray path is confined to the region between roughly 100- and 1000-km altitude, and that the whistler energy can echo back and forth between these levels. The SP phenomenon occurs mostly at night, typically within a few hours after sunset. SP events are often observed over a period of one or two hours in duration and, for a single Alouette pass, have been observed over a north-south range as great as 2000 km in extent. The evidence suggests that the SP phenomenon occurs mostly near sunspot minimum and at dipole latitudes greater than 45 degrees.

Carpenter, D. L., C. G. Park, and H. A. Taylor, Jr., "Multi-experiment Detection of the Plasmopause," submitted to the AGU for the Washington, D. C. meeting in April 1968.

ABSTRACT: Three independent means of detecting the plasmopause have been compared: 1) OGO-I and OGO-III mass spectrometer data on proton density; 2) broadband VLF recordings (0-12.5 khz) on OGO-I and OGO-III; 3) whistlers recorded at ground stations Eights and Byrd, Antarctica, near the 90°W meridian. (In the OGO VLF data, plasmopause crossings appear as abrupt changes in whistler activity, often accompanied by noise bands of limited duration.) The

study included six OGO-I passes during May and June 1965 and the outbound OGO-III pass of 5 July 1966. Satellite plasmopause crossings occurred between 0730 and 2250 LT and between 17° and 42° geomagnetic latitude. The observed magnetic shell parameter of the plasmopause varied from 3.2 to 5.5 R_E . Simultaneous ground and satellite recordings with a local-time separation of about 1 hour show agreement on the plasmopause radius within experimental error of $\pm 0.2 R_E$. For larger local-time separations, the measurements agree well with the expected 3-dimensional properties of the plasmasphere. On OGO-I, inbound on 9 June 1965, and on OGO-III, outbound on 5 July 1966, plasmopause crossings detected by the onboard VLF receiver and mass spectrometer agreed within $<0.1 R_E$ in plasmopause radius. These results also agreed with available ground whistler measurements. The findings of agreement between the ground whistler data and the satellite H^+ data should not be generalized, but appear to apply to at least a large class of OGO orbits.

Dunckel, N., and R. A. Helliwell, "Whistler and VLF Emission Intensities Observed in the Magnetosphere by the OGO-I Satellite," presented at the April 1966 Joint URSI-IEEE Spring Meeting, Washington, D. C.

ABSTRACT: Measurements of whistlers and VLF emissions at altitudes up to ten earth radii have been made using the Stanford University/Stanford Research Institute VLF/LF receiver on board the OGO-I satellite.

When the satellite is close to the magnetic equator, whistlers are sometimes detected out to L-values of 5 earth radii; however, they are much more common on lower L-shells. The range of occurrence is thus comparable to that of ground whistlers. The highest observed rate of whistler occurrence near the equator, is 45 whistlers per minute at an L-value of 3.2.

When the satellite is far from the magnetic equator whistlers are sometimes detected out to L-values of 6 but again are much more common at lower L-values. The highest observed rate, as measured from dynamic spectra, is 475 per minute at an L-value of 2.7. The strongest whistler observed by the satellite was observed during daytime and had a magnetic intensity of $2 \times 10^{-2} \gamma$.

VLF emissions have been detected by the satellite out to L-values of 9 and beyond. Chorus is detected more than half the time during which the satellite lies within an L-shell of 9. The strongest chorus ever observed, detected at $L = 5$ and at a magnetic latitude of 40° , had a magnetic intensity of $6 \times 10^{-2} \gamma$.

The L-value of this observation corresponds to that of the maximum chorus detected by Injun III, but the amplitude is seven times stronger than the maximum reported for chorus detected by Injun III. Hiss is less common than chorus and may have a tendency to be restricted to L-values between 3 and 6.

Samples of the data taken by the sweeping receivers when the satellite is close to the magnetic equator have been used in an effort to determine the average VLF signal strength in this region. This average will be compared to the requirements for limitation of trapped particle fluxes by whistler-mode wave interactions.

Dunckel, N., and R. A. Helliwell, "A Study of Emissions Observed in the Magnetosphere and Transition Region," presented at URSI Meeting, Palo Alto, Calif., December 7-9, 1966.

ABSTRACT: The upper cutoff frequency, f_u , of VLF emissions detected by the OGO-I satellite was measured over magnetic latitudes from 0 to 50 degrees and from $L = 3$ to the boundary of closed field lines as determined by Mead [1964] and Williams and Mead [1965]. The ratio of f_u to f_{H_0} , the gyrofrequency at the top of the line of force passing through the satellite, averaged approximately 0.5, seldom exceeded 1.0, and was independent of geomagnetic latitude. These results provide strong support for the theory that emissions are generated by electrons in the vicinity of the magnetic equatorial plane.

Using the temporal and spatial occurrence of emissions as determined from OGO-I data, the diurnal variation of the occurrence of emissions at certain high-latitude VLF ground stations was predicted and found to be in good agreement with observations of emissions at those stations.

Edgar, B. C., "Anomalous Nose Whistlers in OGO-I," presented at the December 1966 Joint URSI-IEEE Meeting, Palo Alto, California.

ABSTRACT: Anomalous nose whistlers have been observed on OGO-I in a region extending twenty degrees to each side of the geomagnetic equator and from $L = 1.9$ to $L = 2.5$. These anomalous whistler traces are usually characterized by the following: nose frequencies of 4 kHz or lower, three or more well-defined individual components, and a component spacing pattern that depends on the geomagnetic latitude.

It was initially proposed by Smith that these whistler traces are produced by lightning energy traveling over non-ducted paths that begin at different points at the base of the ionosphere. A ray tracing computer program including the effects of ions, initially developed by Kimura and later modified for better accuracy by R. L. Smith and B. C. Edgar, has been used successfully to predict the dispersion, shape, spacing, and nose frequencies of the anomalous nose whistlers, with good agreement with the OGO-I data. The diffusive-equilibrium model of the magnetosphere used, contained three ions, hydrogen, oxygen, and helium. A discussion of the computer results will include the sensitivity of the predicted dispersion curves to the relative ion concentrations.

Edgar, B. C., and R. L. Smith, "A Computer Ray Tracing Interpretation of Certain Aspects of Magnetospherically Reflected Whistlers," presented at the October 1967 URSI Fall Meeting, Ann Arbor, Michigan.

ABSTRACT: Since the discovery of magnetospherically reflected (MR) whistlers on the OGO-I satellite, it has been shown that a computer ray tracing program, with ion effects included, can predict the spacing patterns and general shapes of observed MR whistlers as reported by Edgar and Smith. Recent investigations using the computer ray tracing program and the OGO-I MR whistler data show that:

(1) Observation of MR whistlers is generally confined to a region in the magnetosphere bounded by L -shells of 1.5 and 3.0 and by geomagnetic latitudes of 40°N and 40°S . Corresponding limits for starting latitudes of the ray paths are found from analysis to lie between 50°N and 15°N for sources in the northern hemisphere.

(2) The nature of ion composition at a base level of 1000 km in a diffusive equilibrium density model affects the spacing patterns and the nose frequencies of the predicted MR spectrograms. A model consisting of 50% H^+ and 50% O^+ at the base level seems to give best agreement with the data. Increasing the H^+ concentration to 75% and the O^+ concentration to 25% affected the spacing pattern quite adversely. The use of 25% He^+ with 50% H^+ and 25% O^+ tended to lower the predicted nose frequency by 1 kHz.

(3) For the model consisting of 50% H^+ and 50% O^+ at the base level, the computed spacings between MR traces were found to be very sensitive to the magnetic equator position relative to the satellite location. The required accuracy in the computation of the magnetic equator position was obtained using the Jensen-Cain formulation of the magnetic field.

A discussion of the emissions associated with MR whistlers with emphasis on the differences between emission and propagation effects will also be included.

Edgar, B. C., and R. L. Smith, "Magnetospherically-Reflected Whistlers in OGO-I," 1966 Fall URSI Meeting, Stanford, California, p. 68, 1966.

Helliwell, R. A., "VLF Noise of Magnetospheric Origin," presented at the 1966 URSI General Assembly, Munich, Germany.

ABSTRACT: Periodic emissions were found to have the same period as two-hop whistlers at the same frequency, giving further support to the hypothesis that each emission is triggered by the whistler-mode echo of the previous emission. Evidence was found that the susceptibility of the medium to triggering is reduced in the period (order of one second) just following an emission. This relaxation effect was used to explain the predominance of symmetrical three-phase periodic emissions.

Detection of discrete emissions triggered by VLF Morse code dashes (150 ms), but seldom by dots (50 ms), showed that the medium tends to be continuously susceptible to triggering and that the process of triggering is strongly dependent on signal duration. A tendency was found for the artificially-stimulated emissions to start at a frequency a few hundred cycles above the frequency (14.7 kc/s) of the triggering signal. Triggering of emissions at 10.2 kc/s by low power Omega signals occurred preferentially on the path whose minimum gyrofrequency is about twice the wave frequency.

Aurora-associated hiss was found to center in the auroral zone and to extend in frequency from 4 kc/s to over 20 kc/s, with some bursts extending up to as high as 600 kc/s. Hiss was found to increase with small increases in riometer absorption, but to decrease when riometer absorption exceeded several db. Hiss was found to peak in winter and near midnight, indicating at least partial control by D-region absorption. Associations were found between hiss and other phenomena, including sporadic E, 28 Mc/s noise bursts and 18 Mc/s radar echoes from field-aligned ionization in the auroral zone.

In the auroral zone characteristic temporal variations of VLF emissions in conjunction with other phenomena were observed. The dominant pattern at night showed the following sequence: 1) steady VLF hiss and weak aurorae, 2) impulsive hiss and auroral breakup together with absorption and impulsive micropulsations (Pi), 3) strong absorption, no hiss (probably cut off by the absorption), strong continuous micropulsations (Pc) and VLF chorus (1 kc/s). During daytime the dominant features were chorus (1 kc/s), micropulsations (Pc) and absorption, with VLF hiss being observed occasionally at the beginning of a day event. The chorus at 1 kc/s (often called polar chorus) was found to peak in summer.

Long-period pulsations, or quasi-periodic emissions, having periods of the order of a minute, were found to consist of bursts of emissions usually showing a rising frequency characteristic. They were shown to appear simultaneously in opposite hemispheres and have been attributed to modulation by hydromagnetic waves of the parameters of the emission mechanism. A new class of quasi-periodic emissions was identified, in which the period was directly associated with certain properties of the whistler-mode periodic emissions making up the groups of the quasi-periodic emission.

Rocket and satellite observations show strong emissions that often are not seen on the ground. Satellite observations have revealed an unusual band of noise apparently related to the lower hybrid resonance frequency. This band is frequently stimulated by both upgoing and downcoming whistlers and a wave trapping effect has been suggested as an important factor in the production of the noise. Evidence was found that VLF hiss is generated at and above the high-latitude trapping boundary for 40 Kev electrons and that it correlates with fluxes of precipitated electrons of lower energy ($E > 10$ Kev).

Theoretical work confirmed the inadequacy of any known incoherent radiation mechanisms to explain the observed intensities of VLF emissions. Mechanisms based on the assumption of coherently radiating bunches of electrons were advanced and criticized. The transverse resonance instability was advanced to get around the limitations of the 'particle-bunch' theory. However, no completely satisfactory explanation of the spectral shapes of discrete emissions has yet been offered.

Through theoretical analyses, the precipitation of energetic particles was linked to the generation of VLF emissions. It was shown that whistler-mode noise leads to electron pitch angle diffusion which in turn results in particle precipitation.

Helliwell, R. A., D. L. Carpenter, N. Dunckel, J. P. Katsufakis, R. L. Smith, L. H. Rorden, B. P. Ficklin, H. Guthart, and L. E. Orsak, "Whistler Mode Propagation and Natural Noise Observed in the OGO-I VLF Experiment," presented at the April 1965 AGU Meeting, Washington, D. C.

Helliwell, R. A., "A Theory of Discrete VLF Emissions from the Magnetosphere," *J. Geophys. Res.* 72, 4773-4790, October 1967.

ABSTRACT: Some of the spectral forms (e.g. 'inverted' hook) of discrete VLF emissions are not explained satisfactorily by present theories of generation based simply on gyroresonance between energetic streaming electrons and whistler-mode waves traveling in the opposite direction. An extension of the gyroresonance idea is proposed in which the *spatial variations* of the electron gyrofrequency and the Doppler-shifted wave frequency are matched. The coupling time between a

resonant electron and the wave is then maximized, and hence the output wave intensity is maximized. Application of this condition leads directly to an expression for the time rate of change of emission frequency in terms of the location of the interaction region. An approximate analysis of the postulated interaction process leads to a theorem that states: The magnetic field intensity is limited to a value less than that at which the bunching time approximately equals the resonance time. When the input particle flux exceeds the value required to account for this limiting value of wave intensity, the interaction region drifts downstream. If the interaction begins on the falling-tone or 'upstream' side of the equator, positive drift carries the interaction across the equator into the rising-tone region, giving rise to the well known 'hook' shape. Reversal of the drift, resulting from wave damping or other factors, carries the interaction back across the equator, giving rise to the inverted hook, a shape not explained by previous theories. Combinations of positive and negative drifts can explain the principal emission forms. The triggering delay and offset frequency of artificially triggered discrete VLF emissions can be explained by the theory.

Helliwell, R. A., "VLF Emissions Observed in the Magnetosphere," paper presented at TRW, Redondo Beach, Calif., November 17, 1966.

ABSTRACT: Strong magnetic noise has been found in the magnetosphere using the Stanford/SRI multi-purpose OGO-I VLF/LF receiver. Within the band of observation, 300 Hz to 100 kHz, three main types have been identified: 1) high pass noise, 2) broadband noise, and 3) low pass noise. The low pass noise is observed only at frequencies below the local gyrofrequency and is similar in spectral character to whistler-mode VLF emissions observed on the ground. It peaks on the day side of the earth near $L = 3$ and again near $L = 10$.

The upper cutoff frequency, f_u , of low pass noise detected by the OGO-I satellite was measured over magnetic latitudes from 0 to 50 degrees and from $L = 3$ to the boundary of closed field lines as determined by Mead [1964] and Williams and Mead [1965]. The ratio of f_u to f_{H_0} , the gyrofrequency at the top of the line of force passing through the satellite, averaged approximately 0.5, seldom exceeded 1.0, and was independent of geomagnetic latitude. These results provide strong support for the theory that this type of noise is generated by electrons in the vicinity of the magnetic equatorial plane.

Heyborne, R. L., "Observations of VLF Signals in the OGO-I Satellite," presented at the October 1965 URSI Meeting, Dartmouth.

ABSTRACT: Preliminary OGO-I data have made possible for the first time a detailed study of attenuation rates of very low frequency man-made whistler-mode signals propagating through the ionosphere and into the magnetosphere.

While LOFTI provided whistler-mode data to maximum altitudes less than 1,000 km, the OGO-I orbit extends well beyond the magnetosphere permitting VLF observations to altitudes at which normal whistler-mode propagation cuts off.

Whistler-mode signals from VLF and LF stations are received at the satellite by a 12.5- to 100-kc receiver which is normally in a sweeping mode, but which on command can be operated in a fixed-frequency mode for receiving a specific station. Useful data have been obtained in each mode.

Particularly good data were obtained from station NPG (18.6 kc, 200 kw) on 17 Feb. 1965. Maximum field strengths at the satellite of approximately 40 db below 1 gamma were obtained over a path having an earth-ionosphere waveguide distance of 300 km and a field line distance of 7,500 km. Minimum observed field strengths were approximately 75 db below 1 gamma over a path having a waveguide distance of 2,500 km and a field line distance of 13,600 km.

Predicted signal power has been computed on the basis of a model path having three major sources of loss: (1) excitation of the whistler-mode at the foot of the field line passing through the satellite, (2) absorption of the signal in passing through the lower ionosphere, (3) divergence within the ionosphere.

Calculated values show good agreement with measured values.

Heyborne, R. L., "Observations of Whistler-Mode Signals in the OGO Satellites from VLF Ground Station Transmitters," presented at the December 1966 Joint URSI-IEEE Meeting, Palo Alto, California, Stanford University Radioscience Technical Report SU-SEL-66-094, Nov. 1966.

ABSTRACT: In the ionospheric plasma, electromagnetic propagation is possible at frequencies below the plasma frequency and the electron gyrofrequency. This mode of propagation is commonly known as the whistler mode.

Amplitude calibrated receivers aboard two satellites (OGO-I and OGO-III) are used to receive signals propagating in the whistler mode from U. S. Navy VLF stations on the ground. Existing theory is utilized to calculate the expected intensities of these signals. Measured and calculated intensities are then compared.

The two satellites effectively sub-divide the whistler mode path into two main parts: (1) the earth-ionosphere waveguide loss, the boundary and excitation loss, and the absorption loss through the ionosphere to the altitudes of OGO-II and (2) losses due to divergence of the signal between OGO-II and the higher altitudes of OGO-I plus any additional absorption above OGO-II. These data are utilized to determine more precisely the major features and loss characteristics of whistler-mode paths inferred from previous experiments, and to determine the accuracy of attenuation rates predicted earlier by theoretical means.

It is concluded that the average intensity of VLF whistler-mode signals in the magnetosphere may usually be predicted to an accuracy of ± 10 db by the use of available models and existing theory. This study strongly supports present understanding of the major features of whistler-mode propagation which until now has been based largely on theoretical developments and experimental observations of naturally occurring phenomena.

Several new observations have been made. These include:

(1) A Northern hemisphere latitudinal cutoff of VLF signals. Signal intensities have been observed to decrease as much as 40 db as OGO-III moves from approximately 59° to 60° Northern geomagnetic latitude. Signals are seldom observed at latitudes above the cutoff region. There is evidence that the cutoff is more pronounced during the daytime and when the geomagnetic planetary K_p index is high. It is hypothesized that the $N\nu$ product in the D and E regions of the ionosphere increases rapidly with latitude near the cutoff region. The evidence suggests that the observed cutoff is consistent with an absorption explanation.

(2) Strong enhancements of VLF signals near the antipodes of VLF transmitters. Enhancement factors as high as 25 db have been observed when the satellite flies within 200 km of the antipode. Enhancements have also been observed near the magnetic conjugate of the antipode.

(3) A pronounced dip in the intensity of VLF signals over the geomagnetic equator. Seen at all longitudes, both daytime and nighttime, the magnitude of the equatorial dip is typically 12 to 20 db during the daytime and 5 to 10 db during the nighttime. The observation is explained on the basis of absorption.

(4) A band of intense noise at 18 kHz around both polar regions. The intense noise is observed in a band 3 to 11 degrees wide centered near 75 degrees geomagnetic latitude. Occurrence of the noise exhibits seasonal dependence with local summer rates higher than winter. Although there is evidence that the intense noise is more likely to be observed during magnetically disturbed periods, fluctuations in the noise magnitude can not be explained by fluctuations in the K_p index.

Heyborne, R. L., "Propagation Factors in the Fixed-Frequency Whistler-Mode as Determined from VLF Ground Station Signals Received in the OGO Satellite," presented at the April 1966 Joint URSI-IEEE Spring Meeting, Washington, D. C.

ABSTRACT: Data from amplitude-calibrated receivers aboard the OGO-I satellite are providing new insights to the subject of fixed-frequency whistler-mode propagation. Since Sept. 1964 these receivers have provided amplitude information on signals propagating via the whistler-mode from VLF transmitters NAA in Cutler, Maine and NPG in Jim Creek, Washington. The OGO-I orbit extends well beyond the magnetosphere, hence fixed-frequency whistler-mode data has been obtained to altitudes at which this mode of propagation cuts off.

Field intensity at the satellite has been calculated on the basis of a model path having three major sources of loss: (1) excitation of the whistler-mode at the foot of the field line passing through the satellite, (2) absorption of the signal in passing through the ionosphere, (3) divergence within the ionosphere.

Conclusions such as the following are indicated from a comparison of the calculated and measured values: (1) VLF absorption rates integrated through the lower and upper ionosphere appear to be lower, by a factor of 8 to 12 db, than rates predicted in the literature, (2) field intensities of transmitted VLF ionosphere waves at large distances (4 to 10 km) from a short vertical antenna on the ground are greater, perhaps by an order of magnitude, than calculated values based on ray theory. For example, NAA daytime field intensities of 73 db below 1 gamma were recorded on 18 Sept. 1965 over a path having an earth-ionosphere waveguide distance of 5,000 km and a field line distance of 12,000 km. Calculations based on predicted absorption and excitation rates indicate that the intensity should have been no greater than 103 db below 1 gamma.

In addition to providing new limits on the major sources of loss in whistler-mode propagation per se, the data appears to be valuable in studying some of the properties which are not so well defined. These include such things as ducting, determination of electron densities and total tube content, and determination of particle streaming velocities in the magnetosphere.

Price, G. H., "Propagation of Electromagnetic Waves into Anisotropic Media from an External Point-Dipole Source," *Radio Science*, 2, (New Series) 607-618, June 1967.

ABSTRACT: A formal solution to the problem of determining the fields generated by an infinitesimal, arbitrarily oriented, electric-dipole source located in an isotropic medium bounded by parallel plane-stratified, anisotropic media is derived.

Rorden, L. H., L. E. Orsak, and B. P. Ficklin, "Non-Whistler-Mode Noise Bursts Observed on OGO-I," presented at the April 1966 Joint URSI-IEEE Spring Meeting, Washington, D. C.

ABSTRACT: Two types of non-whistler-mode noise bursts that are frequently observed at relatively high altitudes by the Stanford University/Stanford Research Institute VLF Experiment on board the OGO-I satellite will be discussed. Since these observations were first reported (Helliwell, et al, 1965) reduction and analysis of additional data from the sweeping receivers, which measure magnetic fields in the frequency range .2 to 100 kc, has established that these phenomena are not propagated in the whistler mode, since they are observed predominantly above the electron gyrofrequency. Also, they do not appear to be chorus, hiss, or signals that have been observed at lower altitudes by OGO-I and on the ground.

The first type of noise burst is present at all frequencies from .2 to 100 kc including frequencies much greater than the local gyrofrequency and less than the local plasma frequency; therefore, this noise is probably not a propagating disturbance. Spin modulation is frequently observed which would not be present for a propagated wave. It is suggested that their source is a plasma interaction in the vicinity of the spacecraft. The second type of noise burst contains energy at frequencies above a definite lower cutoff (always above 20 kc). It is suggested that these bursts are energy propagated above the maximum plasma frequency between the source and OGO-I. The two types are frequently observed continuously and possibly overlapping, and it is believed that they are related. Both types of bursts display a strong magnetic latitude dependence and occur most frequently at midlatitudes (30 to 50 degrees) but seldom below 20 degrees. These bursts are not generally observed in the subsolar region between 0900 and 1500 local mean time, but have been observed out to 25 earth radii within the magnetosphere.

Rorden, L. H., L. E. Orsak, B. P. Ficklin, and R. H. Stehle, "Instruments for the Stanford University/Stanford Research Institute VLF Experiment (4917) on the EOGO Satellite," Stanford Research Institute Instrument Report, May 1966.

Smith, R. L., "Non-Ducted Whistlers in the Magnetosphere," presented at the April 1966 Joint URSI-IEEE Spring Meeting, Washington, D. C.

ABSTRACT: A common type of whistler observed in the OGO-I satellite is swishy, (has a large spread of time delays) at high frequencies but is fairly pure at the lower frequencies. The appearance resembles that of a nose whistler, but the apparent nose is frequently at a much lower frequency than that expected for longitudinal propagation to the satellite. For example, in one case the apparent nose frequency was 3 or 4 kHz when the expected nose frequency was 10 kHz. Sometimes the rising portions do not join continuously to the main trace. Other whistlers observed in the same general region do not show the swishy tops and their nose frequencies are closer to the expected value. However, their low frequency dispersions are close to those described above.

Storey (1953) pointed out that propagation delay for frequencies much less than the gyrofrequency is nearly independent of wave normal angle. Smith (1960) showed that for somewhat higher frequencies, whistler waves traveling with large wave normal angles have large propagation delays compared to nearly longitudinal propagation which can occur within field aligned columns of enhanced ionization.

We suggest therefore that the new class of whistlers described above are the result of non-ducted propagation. The lower frequencies would not be affected as much as the higher frequencies, and a small amount of scattering would cause the higher frequencies to have a large spread of time delays.

Smith, R. L., and J. J. Angerami, "Magnetospheric Properties Deduced from OGO-I Observations of Ducted and Non-Ducted Whistlers," *J. Geophys. Res.*, 73, 1-20, January 1968.

ABSTRACT: The OGO-I satellite has yielded evidence for both ducted and non-ducted modes of whistler propagation in the magnetosphere. Two new types of non-ducted whistlers have been identified: the "Magnetospherically Reflected" whistler and the "Nu" whistler. These whistlers have never been observed on the ground. Their unique properties result in part from the presence of ions which permit reflection of whistler-mode energy in the magnetosphere. These phenomena provide a new tool for study of the distribution of ionization in the magnetosphere. Ducted whistlers from OGO-I have provided the first in situ observations of whistler ducts. Near $L = 3$, the equatorial separations between ducts ranged from 50 km to 500 km, and the equatorial thicknesses were about 400 km. The analysis yielded independent experimental support for the diffusive equilibrium model of distribution of ionization along the field lines in the plasmasphere. Some evidence was found of distortion of the magnetic field on the nightside at $L \sim 3$, possibly due to oblique incidence of the solar wind on the earth's field.

4920 (Wolff, Wyatt, Gegenschein Photometry)

Paddack, S. J., "Gegenschein Orbital Parameters and Operational Schedule," GSFC X-643-64-133, Preprint.

ABSTRACT: A technique for defining the location of the Eccentric Orbiting Geophysical Observatory (EGO), S-49, in the gegenschein reference frame is presented. The gegenschein reference frame is an orthogonal coordinate system with its origin at the center of the earth and its fundamental plane lying in the ecliptic plane with one of the axes in this plane pointing directly away from the sun. An operational schedule for the gegenschein experiment is predicted. Since the experiment device cannot tolerate direct or reflected sunlight, the gegenschein experiment package is placed on the dark side of the solar array. The position of the satellite in the gegenschein coordinate system is a function of the orbit and position of the sun. The field of view problem is a function of the location of the satellite, earth and moon, and solar array position, the latter because the gegenschein experiment package rotates with the solar array. As a result of the application of these techniques in computer programs, the position in the gegenschein coordinate system versus time of the EGO is derived, and an operational schedule as a function of solar array angle is presented.

Author

Wolff, C. L., "The Effects of the Earth's Radiation Belts on an Optical System," presented at the September 1965 Optics in Space Conference, Southampton, England, *Applied Optics* 5, 1838, 1966, also GSFC X-641-65-433, Preprint.

OGO-I TECHNICAL PAPERS

Blair, W. E., and B. P. Ficklin, "Summary of Digital Data-Processing Systems for the OGO SU/SRI Very-Low Frequency Experiments," Stanford Radioscience Laboratory Summary Report, July 1967.

ABSTRACT: This report summarizes the computer digital data-processing techniques for the Stanford University/Stanford Research Institute (SU/SRI) very-low-frequency (VLF) radio noise and propagation experiments aboard the OGO satellites. Specifically, the processing system outputs for the VLF experiments aboard OGO-I (A-17), OGO-II (C-02), and OGO-III (B-17) are briefly described. These outputs are contiguous 16-mm cine films on which the data are plotted and pertinent satellite and geophysical parameters are listed. The cine films are described, and the advantages of the system for compacting, scanning, accessing, and analyzing the data are stated.

Ferris, A. G., H. L. Hoff, and W. E. Scull, "Orbiting Geophysical Observatory OGO-A Operations Plan 11-64," August 1964, GSFC X-535-64-219, Preprint.

ABSTRACT: The primary objective of the Orbiting Geophysical Observatory (OGO) program is to conduct large numbers of significant, diversified geophysical experiments for obtaining a better understanding of the earth-sun relationships and the earth as a planet.

The secondary objective of the program is the development and operation of a standardized observatory-type oriented spacecraft, consisting of a basic structure and subsystems design which can be used repeatedly to carry large numbers of easily integrated scientific experiments in a wide variety of orbits.

The first mission in the OGO program is the OGO-A, an Eccentric Orbiting Geophysical Observatory (EGO). The objective of the OGO-A is to make experimental measurements over a wide range of distances from the earth, from the region where sounding rockets and low altitude satellites are effective, to extra-terrestrial space where the earth's magnetic field and atmosphere no longer alter the characteristics of the phenomena to be observed. The experiments selected for the OGO-A and later missions will extend our understanding of energetic charged particles, low energy charged particles, magnetic and electric fields, micrometeorites, ultraviolet scattering near the earth, X-rays and gamma rays, VLF phenomena, radio noise phenomena, and ionospheric aeronomy phenomena in the region near the earth.

Ficklin, B. P., R. H. Stehle, C. Barnes, and M. E. Mills, "The Instrumentation for the Stanford University/Stanford Research Institute VLF Experiment (B-17) on the OGO-III Satellite," Stanford Research Institute Supplemental Report, May 1967.

ABSTRACT: The Stanford University/Stanford Research Institute VLF Experiment B-17 instrumentation launched on the OGO-III satellite on 4 June 1966 is a modified version of the Experiment A-17 instrumentation launched on the OGO-I satellite in 1964. Both the experiment on OGO-I and that on OGO-III measure the VLF noise in the satellite orbits (from 200 Hz to 100 kHz in contiguous narrow bands, and from 300 Hz to 12.5 kHz in a single broad band), the magnitude of the impedance of a magnetic dipole, and the relative phases of signals from ground transmitters. In addition, noise measurements by Experiment B-17 extend down to 15 Hz—to permit observation of proton whistlers to altitudes up to four earth radii. Experiment B-17 also allows observation of electrical fields, as well as magnetic fields, on command, and measures the magnitude of impedance of an unsymmetrical electrical dipole in the magnetoplasma. This supplemental report describes the physical and electrical characteristics of the Experiment B-17 instrumentation and presents prelaunch calibration data.

Ficklin, B. P., M. E. Mills, W. E. Blair, N. D. Schlosser, J. H. Wensley, and W. H. Zwisler, "OGO-I VLF Experiment A-17 Digital Data Processing System," Stanford Radioscience Laboratory Final Report, 10 July 1967.

ABSTRACT: This report is concerned with the digital data processing technique of the Stanford University/Stanford Research Institute VLF radio noise and propagation experiment (A-17) aboard the OGO-I satellite. Descriptions, operational procedures, and details of the instrument and satellite are given as required for understanding of the data processing system. The NASA/GSFC (Goddard Space Flight Center) data acquisition, decommutation, and processing systems are briefly described. The input, output, and operation of the four-phase SRI data-processing system are presented in detail. The computer display system and 16-mm cine film presentation are also described, and examples are shown.

On more than 2×10^5 frames of film, 2×10^8 experimental digital data bits of information covering 99 satellite revolutions have been plotted and stored. This accumulation of data represents more than 10^5 bits

of information per frame and was computer processed at approximately three frames per second. This cine film technique provides capability for:

- (1) Significant data compacting
- (2) Quick scanning of data
- (3) Discrimination between signals and interference
- (4) Recognition of unique data characteristics
- (5) Simultaneous data comparison.

The application of this technique is considered the final phase of the data processing and the initial phase of the data analysis.

"Half-Ton Geophysical Satellite," *Sky and Telescope*, 28, 275-277, Nov. 1964. A64-27093.

ABSTRACT: Description of the Orbiting Geophysical Observatory satellite. It is stated that OGO-I is spinning, instead of keeping one face always toward the Earth and another toward the Sun, as intended. As a result, some of the 20 experiments the satellite is equipped for cannot be performed. All of them have been turned on at least once, and can otherwise function properly. Nevertheless, alternate uses for spin-sensitive equipment had been planned, and scientists from the seven government laboratories and nine universities who are participating expect to obtain enough data to qualify OGO-I as a success. A list gives first the original plan for each experiment and then the status during the latter part of September.

Kane, S. R., K. A. Pfitzer, and J. R. Winckler, "The Construction, Calibration and Operation of the University of Minnesota Experiments for OGO-I and OGO-III," University of Minnesota Technical Report CR-87, September 1966.

ABSTRACT: This report presents our final and best estimates of the response characteristics of the ionization chamber and electron spectrometer experiments flown on the OGO-I and OGO-III satellites. These experiments are officially designated:

- 4909-MB (spectrometer)
- 4909-EP4 (ion chamber)

Ludwig, G. H., and P. Butler, "Description of OGO and IMP Satellites," presented at the April 1965 AGU Meeting, Washington, D. C.

Mahoney, M., and J. J. Quann, "Telemetry Data Processing Plan for the OGO-A Mission," September 1964, GSFC X-545-65-350, Preprint.

ABSTRACT: Data from scientific instruments onboard satellites are recorded on magnetic tapes at the NASA data acquisition network stations and sent to the Data Systems Division, Data Processing Branch for evaluation, processing, reduction, and further preparation for analysis. Further responsibilities include spacecraft attitude computations, additional processing of experiment data by request of the experimenter, and processing of spacecraft subsystem data. A telemetry data processing plan has been prepared to help accomplish the above-mentioned tasks for the Orbiting Geophysical Observatories (OGO-A Mission).

The OGO's, the first of a series of sophisticated scientific satellites, have been designed to accommodate many types of highly diversified scientific and technological experiments that will telemeter back to earth an avalanche of data. The techniques of reducing and processing these data require specific knowledge of the data processing problem with all of its aspects: i.e., the control of the experiment data in the OGO's, the data transmission, acquisition, etc., to the data's final preparation for analysis. Therefore details of the extensive data processing operations as well as pertinent OGO spacecraft details are presented in the Telemetry Data Processing Plan for the OGO-A Mission.

The plan contains nine sections and three appendices. Section 1 is the Introduction and Summary. Section 2 presents the overall OGO program, the OGO-A mission, and the observatory tracking equipment. Section 3 presents the multiplexing and transmission of experiments and subsystem data in the OGO-A spacecraft. The multiplexing of data handled by the pulse code modulation (PCM) telemetry is emphasized. Section 4 describes the ground data acquisition stations including procedures, standards, and schedules governing their operations. OGO-A data processing and PCM analog data processing are described in Section 5. OGO-A data processing on digital computers is described in Section 6. Section 7 describes the techniques used to process the PCM digital data in each of the four major intermediate programs of the OGO-A plan. The four major end-data programs for PCM data are described in Section 8. These

programs yield decommutated digital data from commands, experiments, spacecraft subsystems data, and attitude-orbit data. These data together with special-purpose data constitute the end goal of the OGO-A mission. Because it uses frequency-division multiplexing, special-purpose data is separate and distinct from PCM data and must be processed accordingly. Section 9 describes the techniques used to process these data. In conclusion, two appendices present (A) the disposition of data, and (B) the descriptions and locations of experiments and names of experimenters. The command system of the OGO-A spacecraft and the OGO spacecraft instrumentation list are incorporated by reference in Appendix C.

Marsh, F., "OGO Spacecraft OGO-A (S-49) Operation of the Electric Power System in Orbit," May 1964, GSFC X-623-64-126, Preprint.

ABSTRACT: This publication was prepared as an aid to a careful study of the telemetry outputs from the Electric Power System, to see if the telemetry clearly reports the condition of that system. It is the opinion of the writer that the telemetry outputs on D47 and D49 do not clearly indicate the relay configuration in effect in the power subsystems A and B, or the malfunctions which the configurations can show; and that the graph furnished by STL for the reading of these words is further inadequate, in that it lists only 16 instead of 24 or 32 configurations, and does not clearly state what its configurations are.

For most of the words or items on the *Spacecraft Instrumentation List* STL has supplied a series of decimal and octal readout numbers; these readout numbers indicate certain pressures, voltages, temperatures, degrees of rotation, and other units. On some of the words or items, however, the positions of a number of relays are reported out in a single analog item. This latter is true of D47 and D49, which indicate the positions of relays and switches with respect to Charge Regulators 1 and 2, or A and B.

Marsh, F., "Orbiting Geophysical Observatory S-49 Spacecraft Command, Tracking and Telemetry Systems, Section I—Command System," February 1964 changed June 1964, GSFC X-623-62-208, Preprint.

ABSTRACT: In late 1962 a multiple publication was projected, to be entitled *S-49 Command, Tracking, and Telemetry Systems*, with three parts devoted respectively to Spacecraft Systems, Ground Support Systems, and Data Processing System. The original multiple publication was later cancelled.

Draft copies of various sections of the original Part I, on Spacecraft Systems, were released for review on 30 November 1962, 21 December 1962, and 8 May 1963. All sections carried the publication number, X-623-62-208-I.

The present publication is a revision of the sections previously released as draft copies, and the title has been changed to *S-49 Spacecraft Command, Tracking, and Telemetry Systems* to indicate that it pertains to the Spacecraft systems only. Most of the original pages are retained, and the revisions are indicated by lines in the right-hand margins.

The *OGO Spacecraft Instrumentation List*, Revisions G and Partial H, is Appendix I to the present publication.

Montgomery, H. E., and S. J. Paddack, "EGO Orbital Parameters and Heat Inputs," April 1963, GSFC X-643-63-31, Preprint.

ABSTRACT: The Orbiting Geophysical Observatory (OGO) is an actively oriented satellite which will carry up to fifty experiments. The experiments will be oriented relative to the Sun, Earth or the orbit plane. This document presents methods of analysis for computing orbital data, spacecraft angle data and spacecraft heat input data for OGO, and gives specific results for the S-49, Eccentric Orbiting Geophysical Observatory (EGO). The orbital data include the transient behavior of true anomaly, the flight path angle, the distance from the center of the Earth to the satellite, the angle between the line of apsides and the ecliptic plane, and the angle between the projection of the line of apsides on the ecliptic plane and the Earth-Sun Line. The spacecraft angle data include the transient behavior of solar array angle, the orbital plane experiment package (PEP) angle and the OPEP velocity vector angle. The transient heat input data include Earth emitted heat, direct solar heat, direct solar heat and Earth reflected solar heat inputs to all the faces of the main OGO box, the solar array and the OPEP.

Montgomery, H. E., S. J. Paddack, and F. B. Schaffer, "Shades of EGO, S-49," Jan. 1964, GSFC X-640-64-19, Preprint. N64-27251.

ABSTRACT: This report presents shadow data and heat input for the S-49 EGO. It gives times for which each experiment is in the shadow of either the earth, the satellite's main box, or the solar array. It also gives the heat inputs to the experiments as a function of time from launch for one complete orbit. The heat inputs include direct solar radiation, reflected solar radiation, and earth-emitted radiation. Author

Montgomery, H. E., and F. B. Shaffer, "Power Study of Spin Stabilized EGO (S-49)," March 1965, GSFC X-643-65-14, Preprint. N65-21656.

ABSTRACT: An analysis is performed to determine the solar array angle which will provide maximum power output for the Orbiting Geophysical Observatory satellite. Considered are the effects of shadowing by the box and deviation of solar cell short circuit current from a cosine curve. It is assumed: (1) The geometry of the satellite is given. (2) The satellite is spinning about the \bar{k}_B axis. (3) The solar cells have uniform input-output behavior. (4) The deviation of the output from a cosine curve as the angle of incidence of sunlight is varied. Equations for the ratio of average to maximum current generated by the solar array are given. The possible ranges for the angle between the satellite's \bar{k}_B axis and the vector which points from the satellite to the sun, and for the solar array angle are 0° to 180° and 90° to 270° , respectively.

"NASA to Launch First Orbiting Geophysical Observatory," News Release No. 64-213, 30 August 1964, 41, available from the Scientific and Technical Information Division. N64-29334.

ABSTRACT: In a news release by NASA, the features of the OGO-A satellite, its objectives and experiments, launch-vehicle statistics, and the OGO launch sequence are presented.

"OGO-I, First US Orbiting Geophysical Observatory—IQSY—Related Investigations in Space," *IG Bulletin*, 92, Feb. 1965, *American Geophysical Union, Transactions*, 46, 326-332, Mar. 1965. A65-22431.

ABSTRACT: Description of the OGO-I, the first in a US series of large geophysical observatory satellites, launched into a highly elongated Earth orbit on Sept. 4, 1964.

The OGO-I carries 20 experiments contributed by scientists from seven government laboratories and nine universities. The satellite's power supply, attitude- and thermal-control systems, and procedures for communications, and data handling and processing, are briefly discussed. OGO-I carries instrumentation for scientific investigations in the galactic, interplanetary, and planetary regions of space. In galactic space, the satellite is conducting experiments in cosmic rays, radio astronomy, and gegenschein. Interplanetary space experiments include energetic solar protons, solar wind, magnetic fields, solar X-rays, ultraviolet radiation, and micrometeorites. Experiments in planetary space are concerned with composition of the neutral atmosphere, density and temperature of the ionosphere, micrometeorites, magnetic fields, geomagnetically trapped radiation, and VLF emissions. A table gives names of experimenters and their affiliation, together with titles of the experiments, brief descriptions of them, and their current status.

"Orbiting Geophysical Observatory," *NASA Facts, II*, No. 13, 1965. N65-25232.

ABSTRACT: The OGO-I (Orbiting Geophysical Observatory) carries 20 different experiments as compared to the 8 experiments of Explorer XVIII. The principal advantage of OGO is that it makes observations of numerous phenomena simultaneously for extended periods of time. The EGO (Eccentric Geophysical Observatory) traverses the earth's space environment and flies beyond it into interplanetary space. The EGO studies the sun, the intense Van Allen Radiation Region that surrounds the earth, and the electrons and protons constituting the solar winds that rush constantly from the sun's turbulent surface. The POGO's (Polar Orbiting Geophysical Observatory) primary goal is to increase knowledge about how fluctuations in solar activity affect the characteristics of earth's atmosphere, ionosphere, and magnetic field. As the earth and OGO revolve around the sun, the solar paddles will require repositioning. By turning the paddles properly every 2 months, OGO engineers can maintain an adequate power supply for the spacecraft.

Russey, R. E., "Vehicle System Integration Requirements and Restraints Document for the Orbiting Geophysical Observatory (S-49, S-50) Spacecraft," GSFC Spacecraft Systems Branch, January 1962.

ABSTRACT: This document is concerned with the technical requirements and restraints which the NASA satellite missions, Orbiting Geophysical Observatories, designated S-49 and S-50, impose on their respective launch vehicles. It is intended that this document define all technical requirements within its scope.

Scully, W., "NASA-GSFC OGO-A Integrated Tracking and Data Acquisition Support Plan," June 1964, GSFC X-535-64-163, Preprint.

ABSTRACT: This integrated support plan was compiled for the purpose of delineating the tracking and data acquisition support which will be provided for the OGO-A project from lift-off to the end of the useful scientific lifetime of the spacecraft. The plan is divided into two major phases:

Pre-Injection — defined as that period from lift-off through Atlas/Agena separation and Agena 2nd cutoff.

Post-Injection — defined as that period from Agena 2nd cutoff through the useful scientific lifetime of the spacecraft.

for the purpose of clarity. It defines the project tracking and data acquisition requirements (both vehicle and spacecraft), the areas of responsibility of the various participating organizations, and the techniques and procedures which they will utilize in providing the required support.

Much of the information contained in this plan was obtained from existing documentation which was concerned with specific requirements and areas of support. It is the intent of this plan to combine and further clarify these separate plans into an integrated tracking and data acquisition support plan which will contain the total project requirements and the support provided thereto.

Stewart, D. J., and J. J. Fleming, "Orbit Determination Plan for the Satellite OGO-A," August 1964, GSFC X-547-64-239, Preprint.

ABSTRACT: The primary objective of the Orbiting Geophysical Observatory (OGO-A) Satellite is to conduct large numbers of significant, diversified geophysical experiments for obtaining a better understanding of the earth-sun relationships and the earth as a planet. The secondary objective of the program is the development and operation of a standardized observatory-type oriented spacecraft, consisting of a basic structure and sub-systems design which can be used repeatedly to carry large numbers of easily integrated scientific experiments in a wide variety of orbits. As a design objective for the standardized spacecraft, it is desired that the spacecraft can be capable of operation for a period of one year, during which the orientation of portions of the spacecraft toward the sun, the earth and in the orbital plane can be accomplished.

The satellite is to be launched to the southeast from Cape Kennedy. Nominal values for the principal elements are as follows:

Period, minutes	3,831
Perigee height, s. m.	171
Perigee height, km	275
Apogee height, s. m.	92,698
Apogee height, km	149,184
Inclination, degrees	31

The Satellite will be separated from the second stage about 56 minutes after lift-off.

TRW/STL Monthly Operational Summary Report OGO-I, 5 September to 15 October 1964.

ABSTRACT: This report represents the first in a series of summaries that will be submitted to GSFC on a monthly basis. These reports will list all significant operational events during the in-orbit phase of OGO-I. This first report is delivered under Contract NAS 5-899, and covers the period September 5 to October 15, 1964. The second and subsequent reports will be delivered under Contract NAS 5-9100.

The performance characteristics of the major subsystems of the observatory will be summarized along with experiment operation. Orbit data coverage, temperature and eclipse histories and spacecraft orientation will likewise be reported on a monthly basis.

TRW/STL Monthly Operational Summary Report OGO-I, 15 October to 30 November 1964.

ABSTRACT: This report is the second of a series of Operational Summary Reports to be submitted to GSFC and covers the period October 15 to November 30, 1964. This report and subsequent reports will be submitted under Contract NAS 5-9100.

The next report to be submitted will cover the period December 1 through December 31, 1964 and subsequent reports will be submitted on a monthly basis.

TRW/STL Monthly Operational Summary Report OGO-I, December 1964.

ABSTRACT: This is the third of a series of monthly reports that summarizes the in-orbit performance of OGO-I. This report is submitted under Contract NAS 5-9100 and covers the month of December.

TRW/STL Monthly Operational Summary Report OGO-I, January 1965.

ABSTRACT: This report is the fourth of a series of Operational Summary Reports to be submitted to Goddard Space Flight Center and covers the operational period for the month of January.

TRW/STL Monthly Operational Summary Report OGO-I, February 1965.

ABSTRACT: This report is the fifth of a series of Operational Summary Reports to be submitted to Goddard Space Flight Center and covers the operational period for the month of February.

TRW/STL Monthly Operational Summary Report OGO-I, March 1965.

ABSTRACT: This report is the sixth of a series of Operational Summary Reports to be submitted to Goddard Space Flight Center and covers the operational period for the month of March.

TRW/STL Monthly Operational Summary Report OGO-I, April 1965.

ABSTRACT: This report is the seventh of a series of Operational Summary Reports to be submitted to Goddard Space Flight Center and covers the operational period for the month of April.

TRW/STL Monthly Operational Summary Report OGO-I, May 1965.

ABSTRACT: This report is the eighth of a series of Operational Summary Reports to be submitted to GSFC and covers the operational period for the month of May.

TRW/STL Monthly Operational Summary Report OGO-I, June 1965.

ABSTRACT: This report is the ninth of a series of Operational Summary Reports to be submitted to Goddard Space Flight Center and covers the operational period for the month of June.

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ABSTRACT: This report is the tenth of a series of Operational Summary Reports to be submitted to Goddard Space Flight Center and covers the operational period for the month of July.

TRW/STL OGO-I Experiment Operations Summary, June 1965.

TRW/STL OGO-I Experiment Operations Summary, August 1965.

TRW/STL OGO-I Orbital Operations Final Report, 5 September 1964 to 5 September 1965.

ABSTRACT: This report is an Operations Summary for OGO-I covering the period 5 September 1964 to 5 September 1965. The performance characteristics of the Observatory's major subsystems are herein discussed along with a description of significant operational events experienced during the in-orbit phase of the program.

The OGO-I Orbital Operations Final Report is submitted to the Goddard Space Flight Center under contract NAS 5-9100.

TRW/STL Experiment Data Book, S-49 EGO, OGO-A, for the Orbiting Geophysical Observatory Program, March 1, 1963.

OGO-II DESCRIPTION OF EXPERIMENTS

C-01 RADIO ASTRONOMY, Prof. F. T. Haddock, U. of Mich.

This experiment will measure galactic radio noise at 2.5 and 3.0 Mc to map the distribution at these frequencies.

C-02 VLF EMISSIONS, Dr. R. A. Helliwell, Stanford U.

This experiment will study terrestrial, ionospheric, and extraterrestrial radio-frequency propagation and noise of natural origin in the 0.2- to 100-kc range.

C-03 VLF EMISSIONS, Dr. M. G. Morgan, Dartmouth College

This experiment will measure natural noise and radio propagation in the range of 0.2–10 kc and will provide data on noise and manmade signals as function of time, location, and frequency throughout the observatory's orbit.

C-05 SEARCH MAGNETOMETER, MAGNETIC FIELD FLUCTUATION, Dr. E. J. Smith, JPL, and Dr. R. E. Holzer, UCLA

The objective of this experiment is to investigate the nature of extremely low-frequency variations in the terrestrial field.

C-06 RUBIDIUM VAPOR MAGNETOMETER MAGNETIC SURVEY, Dr. J. C. Cain, GSFC

This experiment will make as detailed a survey as possible of the geomagnetic field; determine the main field and its secular change; study temporal variations in conjunction with simultaneous surface observations; and study the distribution of the sources of the temporal variations.

C-07 IONIZATION COMPARISON OVER THE POLAR REGION, Dr. H. Anderson, Rice Inst., and Dr. H. V. Neher, CIT

This experiment compares the ionization over the polar region with that measured by ionization chambers carried on space probes.

C-08 ENERGETIC PARTICLES SURVEY, Dr. J. A. Simpson, U. of Chicago

This experiment will conduct a determination of 0.3 Mev/nucleon to approximately 30 Mev/nucleon by means of a scintillation telescope.

C-09 CERENKOV DETECTOR, GALACTIC AND SOLAR COSMIC RAYS, Dr. W. R. Webber, U. of Minn.

This experiment will measure the energy spectrum and charged-particle composition of galactic and solar cosmic rays.

C-10 CORPUSCULAR DOWNFLUX RADIATION IN AURORAL AND POLAR ZONES, Dr. J. A. Van Allen, SUI

The experimenter will measure the net downflux of the corpuscular radiation in the auroral zones and over the polar caps.

C-11 SCINTILLATION DETECTOR, LOW ENERGY TRAPPED RADIATION, Dr. R. A. Hoffman, GSFC

This experiment will measure low-energy trapped particles at low altitudes; study the enhancement of protons during magnetic storms; study the precipitation rates, and therefore the source strength, of the trapped radiation; and determine the energy spectrum, intensity, energy flux, and spatial structure of low-energy electrons and protons in the auroral and subauroral zones.

- C-12 PHOTOMETER, AIRGLOW STUDY, Prof. J. Blamont, U. of Paris, and E. I. Reed, GSFC

This experiment will measure airglow in the 6300A, 5577A, and 3914A, and the near-UV region.

- C-13 ULTRAVIOLET ION CHAMBER, AIRGLOW MEASUREMENTS, Dr. P. Mange, NRL

This experiment will provide airglow measurements in the Lyman-alpha and for UV between 1230 and 1350A.

- C-14 ULTRAVIOLET SPECTROMETER, AIRGLOW MEASUREMENTS, Dr. C. A. Barth, U. of Colo., and Dr. L. Wallace, Kitt Peak Nat. Obs.

The experiment will measure the ultraviolet spectra, 1100A to 3400A, of the earth's upper atmosphere to provide data on the nature and energy of the exciting particles, the nature of the excitation process, and the abundance of atomic and molecular oxygen and nitrogen.

- C-15 MASSENFILTER MASS SPECTROMETER, NEUTRAL PARTICLE AND ION COMPOSITION, Dr. L. Jones, U. of Mich.

This experiment will measure the ionic components in the mass range of 0-6 AMU and 0-40 AMU; analyze the ambient neutral particles and ambient positive ions; and investigate the dissociation and diffusive separation of the atmospheric gases and the predominance of helium at the apogee height.

- C-16 BENNETT ION SPECTROMETER, POSITIVE ION STUDY, H. A. Taylor, GSFC

Using a Bennett ion spectrometer, the experiment will make measurements in the mass range of 1-7 AMU and 7-45 AMU. This range covers the low-mass analysis (hydrogen ions) and high-mass analysis (atomic oxygen ions) respectively.

- C-17 BAYARD-ALPERT DENSITY GAUGE, G. P. Newton, GSFC

The experimenter will measure the density of neutral particles. From the density the pressure of the particles can be computed, and from the changes in both pressure and density, the temperature of the neutral particles can be computed.

- C-18 MICROMETEORITE DETECTORS, Dr. C. S. Nilsson, SAO

This experiment will measure the mass distribution, the fluctuations (both in normal space and within meteor streams), and the charge of micrometeorites.

- C-19 ION TRAP, COMBINED RETARDING POTENTIAL ANALYZER, J. L. Donley, GSFC

The experimenter will secure data for a nearly-complete geophysical description of the upper atmosphere and check theories regarding the formation and character of the F region.

- C-20 SOLAR XUV SPECTROPHOTOMETERS, Dr. H. E. Hinteregger, AFCRL

This experiment provides a scanning spectrometer to monitor the solar emission in the 200A to 1600A region.

- C-21 SOLAR X-RAY MONITORING, R. W. Kreplin, NRL

The experiment provides an ionization chamber to measure the solar X-ray emissions in the 0.5-3A, 2-8A, 8-16A, and the 44-60A bands.

OGO-II EXPERIMENTS

C-02 (Helliwell, VLF Emissions)

Angerami, J. J., and R. L. Smith, "Satellite Observations of Whistler Ducts," paper presented URSI Meeting, Ottawa, Ontario, Canada, May 22-25, 1967.

Bell, T. F., "The Artificial Production of VLF Hiss," paper presented URSI Meeting, Ottawa, Ontario, Canada, May 22-25, 1967.

ABSTRACT: In the summer of 1967 an experiment is planned by the Goddard Space Flight Center in which an electron accelerator will be flown aboard an Aerobee 350 rocket from Wallops Island. The purpose of this experiment is to attempt to create auroral spots in the lower ionosphere ($h \sim 100$ km) over Wallops Island by bombarding the lower regions with high energy electrons emitted from the accelerator at high altitude ($h > 200$ km).

An interesting and important side effect of this experiment is the fact that the high energy electrons during their transit from accelerator to lower ionosphere will emit broadband Cerenkov radiation in the VLF frequency range. This radiation will appear as broadband hiss and may be sufficiently intense to observe experimentally. If this is the case, then the opportunity immediately arises to perform an experimental check on the hypothesis that auroral VLF hiss events are caused by Cerenkov radiation from precipitating electrons. On the other hand, if Cerenkov radiation is not observable during the Wallops Island shot it is then of interest to redesign the experiment so that the chances of producing observable Cerenkov radiation are optimized.

It is the purpose of the present paper to estimate theoretically the spatial distribution of the Cerenkov radiation intensity expected to be produced during the Wallops Island experiment and to compare this intensity with estimated minimum observable intensities for both ground based and in situ observations. In addition, methods of programming the accelerator in future experiments are suggested whereby the output of Cerenkov radiation may be enhanced significantly and the chances increased for the successful observation of an artificial VLF hiss event.

Helliwell, R. A., "On the Generation of Discrete VLF Emissions," paper presented URSI Meeting, Ottawa, Ontario, Canada, May 22-25, 1967.

Helliwell, R. A., "A Theory of Discrete VLF Emissions from the Magnetosphere," *J. Geophys. Res.*, 72, 4773-4790, October 1967.

ABSTRACT: Some of the spectral forms (e.g. 'inverted' hook) of discrete VLF emissions are not explained satisfactorily by present theories of generation based simply on gyroresonance between energetic streaming electrons and whistler-mode waves traveling in the opposite direction. An extension of the gyroresonance idea is proposed in which the *spatial variations* of the electron gyrofrequency and the Doppler-shifted wave frequency are matched. The coupling time between a resonant electron and the wave is then maximized, and hence the output wave intensity is maximized. Application of this condition leads directly to an expression for the time rate of change of emission frequency in terms of the location of the interaction region. An approximate analysis of the postulated interaction process leads to a theorem that states: The magnetic field intensity is limited to a value less than that, at which the bunching time approximately equals the resonance time. When the input particle flux exceeds the value required to account for this limiting value of wave intensity, the interaction region drifts downstream. If the interaction begins on the falling-tone or 'upstream' side of the equator, positive drift carries the interaction across the equator into the rising-tone region, giving rise to the well known 'hook' shape. Reversal of the drift, resulting from wave damping or other factors, carries the interaction back across the equator, giving rise to the inverted hook, a shape not explained by previous theories. Combinations of positive and negative drifts can explain the principal emission forms. The triggering delay and offset frequency of artificially triggered discrete VLF emissions can be explained by the theory.

Jorgensen, T. S., "On the Generation of Wideband Electromagnetic Noise Above 1 kHz in the High Latitude Magnetosphere," presented at the 1967 Spring URSI Meeting, May 23-26, 1967, Ottawa, Ontario, Canada.

ABSTRACT: A wideband noise known as auroral hiss is observed at ground-based stations¹ and on satellites² at high magnetic latitudes. During the last decade, several attempts have been made to explain this noise as incoherent Cerenkov radiation from energetic particles in the magnetosphere, but the conclusions were all negative, as the calculated power was several orders of magnitude below the observed power³.

The results of recent observations of auroral hiss and of the low energy electrons with which this noise is strongly correlated suggest that unrealistic models were used in earlier calculations of the total power generated in the magnetosphere by an incoherent Cerenkov process. Therefore it was considered worthwhile to study the Cerenkov radiation again.

This paper discusses a model for a region in space in which the auroral hiss is believed to be generated. It is shown that the total power generated in this region is comparable to the observed power, and it is concluded that auroral hiss may be generated by incoherent Cerenkov radiation from electrons with energies of the order of 1 kev.

¹T. S. Jorgensen, "Morphology of VLF Hiss Zones and Their Correlation with Particle Precipitation Events," *J. Geophys. Res.*, 71, 1367, 1966.

²D. A. Gurnett, "A Satellite Study of VLF Hiss," *J. Geophys. Res.*, 71, 5599, 1966.

³H. B. Liemohn, "Radiation from Electrons in Magnetoplasma," *Radio Science*, 69D, 741, 1965.

Jorgensen, T. S., "Interpretation of Auroral Hiss Measured on OGO-II and at Byrd Station in Terms of Incoherent Cerenkov Radiation," submitted to *J. Geophys. Res.*

ABSTRACT: A wideband noise known as auroral hiss is observed at very low and low frequencies at ground-based stations and on satellites at high magnetic latitudes. Several attempts have been made to explain this noise as incoherent Cerenkov radiation from energetic particles in the magnetosphere, but the conclusions were all negative, as the calculated power was several orders of magnitude below the observed power.

The results of recent observations of auroral hiss and of the low energy electrons with which this noise is strongly correlated suggest that unrealistic models were used in earlier calculations of the total power generated in the magnetosphere by an incoherent Cerenkov process. Therefore it is considered worthwhile to study the Cerenkov radiation again.

This paper discusses a model for a region in space in which the auroral hiss is believed to be generated. It is shown that the total power generated in this region is comparable to the observed power, and it is concluded that auroral hiss may be generated by incoherent Cerenkov radiation from electrons with energies of the order of 1 kev.

Katsufakis, J., "Differences Between the VLF Magnetic and Electric Field Spectra of the Lower Hybrid Resonance (LHR) Emissions and Associated Phenomena," submitted for presentation at the 1968 Spring URSI Meeting, Washington, D. C.

ABSTRACT: Brice and Smith [1965] suggested that the LHR hiss observed on the Alouette I (electric antenna) is characterized by large electric fields, and that this hiss band is found more often on a receiver fed from an electric or dipole antenna than a receiver fed from a magnetic or loop antenna (Injun III).

Since a very large number (~ 2000) of VLF recordings were available from OGO-II and IV (magnetic antenna), a comparative study of the LHR emissions and associated phenomena as observed on OGO-II, IV, Alouette I, Alouette II, and simultaneous ground VLF recordings was undertaken. The results of this study are the following: 1) the LHR hiss band as discussed by Brice and Smith has never been seen on any of the OGO-II and IV VLF recordings; 2) anomalous-dispersion whistler traces associated with the LHR were observed on Alouette I and II and on OGO-II and IV; and 3) the anomalous-dispersion whistler traces observed on OGO-II and IV lend themselves more readily to quantitative analysis, since the LHR hiss is not observed and does not mask out pertinent features of the traces.

The conclusion by Brice and Smith that the LHR hiss is generated in the immediate vicinity of the satellite is still supported. The new and intriguing dispersion anomalies being observed have not yet been interpreted, but possible propagation factors will be discussed.

Brice, N. M., and R. L. Smith, "Lower Hybrid Resonance Emissions," *J. Geophys. Res.*, 70, 71-80, January 1, 1965.

Muzzio, J. L. R., "Reflection of Whistlers in the Ionosphere," submitted for presentation at the 1968 Spring URSI Meeting, Washington, D. C.

ABSTRACT: Evidence for reflection of downcoming whistlers in the upper ionosphere was found in some VLF recordings of OGO-II and OGO-IV. The frequency-time curve of the whistler follows the Eckersley approximation from higher frequencies down to a region where it starts departing toward increased time delays. After passing through a minimum frequency, the signal rises again, sometimes by ~ 200 Hz. For the observed occurrences the satellite height ranges from 450 to 600 km and the minimum frequencies from about 400 to 550 Hz. This corresponds to the region of the first cutoff frequency of the "fast" mode below the proton gyrofrequency. For a downward propagating ray, the refractive index drops considerably in this region and the reflection takes place for frequencies just above the cutoff frequency. The whistlers in question have a dispersion of about $30 \text{ sec}^{1/2}$, which, for the latitudes of observation ($\sim 40^\circ$ geomagnetic latitude) suggests an origin in the conjugate hemisphere. An estimate of the H^+ percentage may be made from a knowledge of the reflection frequency and the local magnetic field intensity. The effects described were reproduced very closely using ray tracing techniques for an assumed model ionosphere with ducts. The presence of ducts was found necessary in order to guide the lower part of the frequency spectrum to the satellite height. Without the ducts the energy in the lower frequencies would be reflected much higher (resulting in an MR whistler) and would not reach the satellite.

Price, G. H., "The Propagation of Electromagnetic Waves into Anisotropic Media from an External Point-Dipole Source," *Radio Science*, 2, (New Series) 607-618, June 1967.

ABSTRACT: A formal solution to the problem of determining the fields generated by an infinitesimal, arbitrarily oriented, electric-dipole source located in an isotropic medium bounded by parallel plane-stratified, anisotropic media is derived.

Wang, T. N. C., and T. F. Bell, "VLF Radiation from Electric Antennas in the Magnetosphere," submitted for presentation at the 1968 Spring URSI Meeting, Washington, D. C.

ABSTRACT: It has long been recognized that the operation of a satellite-based VLF transmitter in the magnetosphere would provide a means of performing a number of important and interesting experiments involving wave-particle interaction phenomena, wave propagation phenomena, and plasma diagnostics.

The usefulness of such a transmitter in performing experimental tasks will be limited ultimately by the amount of power that can be radiated into the plasma from the antenna; in some instances the radiation pattern of the antenna will also play a crucial role.

It is the purpose of the present paper to attempt to obtain some insight into the problem of the coupling between a satellite VLF transmitter system and the magnetospheric plasma by the consideration of some idealized cases. Specifically, we calculate the radiation resistance of a thin electric monopole of arbitrary length oriented either parallel or perpendicular to the static magnetic field, as well as the radiation pattern of a small electric dipole oriented parallel to the static magnetic field.

For the case of the monopole, our results give the radiation resistance explicitly as a function of frequency for a range of frequency between the proton and electron gyrofrequencies.

For the dipole, our results show that in the case of low frequency the radiation pattern is confined within a cone of approximately 20° about the static magnetic field and consists of two parts, a zone of normal radiation fields and a zone of interference fields. The detailed pattern inside the confining cone is calculated.

In conclusion, a discussion is given of the implications of our results with respect to the satellite transmitter problem.

C-03 (Morgan, VLF Emissions)

Laaspere, T., M. G. Morgan, and C. Y. Wang, "Observation of Triggered Lower Hybrid Resonance Noise Bands by Dartmouth's OGO-II Experiment," presented at the COSPAR Meeting, London, July 1967, submitted to *J. Geophys. Res.* for publication.

ABSTRACT: Audio-frequency noise bands of the continuous and triggered types which are evidently associated with the lower hybrid resonance frequency of the ionospheric medium have been observed with Dartmouth's whistler receiver using an electric dipole antenna on OGO-II at heights up to 1500 km (apogee) and at frequencies up to 18 kHz (upper cutoff of the broadband receiver). Previous reports of observations of such bands have all been from the *Alouette* satellites which also carry whistler receivers equipped with electric dipole antennas. In spite of the fact that the electric dipole on OGO-II is much shorter than the antennas of *Alouette*, our results are similar to the *Alouette* observations, and cast some doubt on some other reports according to which intense electrostatic ion waves or plasma oscillations have been detected. A new observation made by Dartmouth's OGO-II experiment is that the upper cutoff frequency of the lower hybrid resonance noise bands triggered by fractional-hop whistlers occasionally displays an envelope which has the shape of an Eckersley whistler. It is concluded that whereas the results of the experiment agree with the interpretation that the lower cutoff frequency of noise bands triggered by whistlers is the lower-hybrid resonance frequency of the ionosphere in the vicinity of the satellite, there is at present no satisfactory explanation of the upper cutoff.

C-05 (Smith, Holzer, Search Magnetometer)

Brody, K. I., R. E. Holzer, and E. J. Smith, "Observations of Magnetic Fluctuations on the OGO-II Satellite," presented at the September 1966 AGU Meeting, Los Angeles, California.

ABSTRACT: The OGO-II triaxial search coil magnetometer has provided data on magnetic fluctuations in the spectral range from 0.01 to 1000 cps at altitudes from 400 to 1500 km. Large changes in the intensity of magnetic activity (1 to 3 orders of magnitude) have been observed in the vicinity of the auroral zones within a spectral range of 0.05 to 5 cps. The enhanced activity, generally located between 67° to 82° geomagnetic latitude, was in the form of bursts occurring within a range of 4° to 12° great circle arc. The extent of the range, as well as its position, was found to be related to local time and the K_p index. The bursts lasted for intervals of 3 to 30 sec, while the satellite was traveling 20 to 200 km. The beginnings and endings of the intervals were exceedingly sharp, with rise and decay times of 1 sec or less. The structure of the signals appears to be similar to hydromagnetic emissions. Comparison of the observations with existing models of hydromagnetic emissions will be made. Additional observations at low geomagnetic latitudes, including helium whistlers, will be discussed.

Brody, K. I., R. E. Holzer, and E. J. Smith, "Search Coil Magnetometer Measurements in the Auroral Zone," presented at the April 1966 AGU Meeting, Washington, D. C.

ABSTRACT: The OGO-II search coil magnetometer, designed to measure fluctuating magnetic fields between 0.01 and 1000 cps, has been in orbit since October 14, 1965. Preliminary data from the first 150 orbits indicate the presence of fluctuating magnetic fields that are substantially enhanced in magnitude in a well defined band some 5° to 7° wide in the vicinity of the auroral zones. The magnetic power density in the spectral range from 0.01 to 5 cps is between 1 and 2 orders of magnitude greater in the auroral zones than at lower geomagnetic latitudes. Both the character of the magnetic spectra and the morphology of the auroral zones will be discussed.

Smith, E. J., R. E. Holzer, J. V. Olson, and R. K. Burton, "Measurements of Magnetic Fluctuations between 1 and 1000 Hz in the Lower Magnetosphere," submitted for presentation at the 1968 Spring AGU Meeting, Washington, D. C.

ABSTRACT: Two Orbiting Geophysical Observatories have been injected into polar orbits. OGO-II, launched in October 1965, varies in altitude between 400 and 1400 km while OGO-IV, launched in July 1967, varies between 400 and 900 km. Both observatories contain triaxial search coil magnetometers that measure naturally-occurring field variations in the frequency range from 1 to 1000 H

Information from a five frequency spectrum analyzer provides near-continuous monitoring of such fields in digital form using an on-board tape recorder. Analog signal waveforms, suitable for detailed analysis, are also available from the OGO Special Purpose Telemetry. The OGO data contain discrete signals such as whistlers, including ion cyclotron whistlers, and emissions. Intense, broad-band signals are also observed in the form of high latitude chorus. The preliminary analysis of the signals present above the ionosphere in this frequency range, including representative frequency spectra, will be reported.

C-06 (Cain, Rubidium Vapor Magnetometer Magnetic Survey)

Cain, J. C., R. A. Langel, and S. J. Hendricks, "First Magnetic Field Results from the OGO-II Satellite," presented at the Ninth Plenary Meeting of COSPAR, May 13, 1966, *Space Research VII* (North-Holland Pub. Co.), 1967, also GSFC X-612-66-305, Preprint.

ABSTRACT: The OGO-II (1965-81A) satellite was launched October 14, 1965 into an orbit with an inclination of 87.4° , perigee of 414 Km and apogee of 1510 Km. Digital samples of the total magnetic field F were obtained with a rubidium vapor magnetometer at 0.5 second intervals (accuracy $\pm 2\gamma$). Root-mean-square differences between the measured field values and those computed from previously derived spherical harmonic expansions were computed. The best comparison of the data is with the GSFC (9/65) field which showed RMS residuals of 47γ . Computation of fields fit to this limited data sample show RMS deviations of 4.1γ using 143 internal spherical harmonics. The residuals from this field show oscillations near the north pole of a few tens of gammas amplitude and irregular structure elsewhere of the order of a few gammas.

Cain, J. C., and S. J. Hendricks, "The Geomagnetic Secular Variation 1900-1965," presented at the International Union of Geodesy and Geophysics 14th General Assembly, St. Gall, Switzerland, Sept. 30, 1967, GSFC X-612-67-479.

ABSTRACT: The GSFC (12/66) model of the main geomagnetic field uses linear and parabolic terms in time to represent secular change over the interval 1900-1965. The predicted field is compared with observatory annual means to investigate systematic residuals. Deviations of the order of 100γ are noted for short spans of years and are observed to occur only in limited regions. Otherwise, the trends of the computed field parallel the observations. Comparisons of secular change charts with those drawn by earlier analyses show good agreement.

The westward drift is generally noted in the vector representation of the harmonic coefficients except that a few terms are seen to undergo predominantly an amplitude change. The components below (g_6^0, h_6^0) that show a recognizable eastward drift are the (3, 2), (5, 1) and (5, 2) terms.

Both dip poles are noted to move smoothly northwestward over the interval whereas the dipole position initially drifts eastward, reverses direction near 1920, and then moves westward at a rate up to about $007^\circ/\text{year}$. Its 1965 position is found to be 78.8°N and 70.0°W .

Cain, J. C., R. A. Langel, and S. J. Hendricks, "Magnetic Chart of the Brazilian Anomaly-A Verification," GSFC X-612-67-373, Preprint.

ABSTRACT: In a recent paper Konovalova and Nalivayko (1967) have reported the results of the Cosmos-26 and 49 satellites (1964-13 and 69 respectively) in mapping the magnetic "low" in total field which centers on southern Brazil. We wish to take this opportunity to compare their results with an evaluation from a recently derived field model which is partly based on the magnetic field experiment from the OGO-II satellite (Cain et al., 1967a). These magnetic survey satellites are contributors to the bilateral cooperation between the U. S. and the USSR for the IQSY World Magnetic Survey (Frutkin, 1965).

Farthing, W. H., and W. C. Folz, "Rubidium Vapor Magnetometer for Near Earth Orbiting Spacecraft," *The Review of Scientific Instruments*, 38, No. 8, 1023-1030, August, 1967.

ABSTRACT: This paper describes the instrumentation and in-flight performance of the rubidium vapor magnetometers being flown by the National Aeronautics and Space Administration on the POGO satellites. An optically pumped, self-oscillating rubidium magnetometer was selected as

being most compatible with the objectives of the study and with the spacecraft capabilities. A four absorption cell configuration is used to reduce the effect of the null zones inherent in these instruments and to obtain accuracies compatible with the scientific objectives of the program. Scalar magnetic field data are obtained in both digital (PCM) and analog (frequency multiplex) form. Instrument performance parameters are monitored through both main frame and subcommutated PCM data. The first instrument orbited was aboard OGO-II which was launched on 14 October 1965. This instrument has returned a large quantity of data, and is still operating when sufficient spacecraft power is available. The accuracy of the data is determined, apart from orbit accuracy, by spurious phase shifts within the instrument. These arise from such sources as optical axis misalignment, electronic nonlinearities and frequency dependence, and propagation delay over the long cables connecting sensor and electronics. The magnitude of the resulting error is inversely proportional to the phase slope of the dual cell absorption line. The total effect in the POGO instrument of these sources of error is an accuracy of better than 1.5γ over the entire instrument range of 15,000 to 64,000 γ .

Heppner, J. P., and D. Reidel, "The World Magnetic Survey," Repr. from *Space Sci. Rev.*, 2, 315-354, 1963, NASA-RP-277. N64-27355.

ABSTRACT: The mathematical and graphical description of the earth's main field has been, and is, a data-limited problem. The World Magnetic Survey (WMS) is an endeavor to minimize this limitation by rapidly and comprehensively blanketing the earth with magnetic field measurements. Satellite surveys, which will play a key role in the WMS, are the principal topic of this paper. Existing magnetic field descriptions, the expected results from new surveys, and the methods of obtaining these results with the POGO satellite are emphasized. Author

Langel, R. A., and J. C. Cain, "OGO Magnetic Field Observations During the Magnetic Storm of March 13-15, 1966," Part 1, Ring Current; and Part 2, The Polar Electrojet, presented at the IAGA Special Events Symposium, St. Gall, Switzerland, Oct. 2, 1967. To be published in a combined form as a reprint. Part 1, GSFC X-612-67-465; Part 2, GSFC X-612-67-473.

ABSTRACT: Magnetic field data from the OGO-II spacecraft and from surface magnetic observatories are analyzed for the period March 13-15, 1966. During this interval there occurred a magnetic storm with a Dst decrease of 122 γ .

The results indicate a non-symmetric inflation of the magnetosphere (asymmetric ring current) with the field decrease in the dusk sector a factor of about three more than that in the dawn sector. Within the 10-30 γ accuracy of the data, the field disturbance at the satellite was equal to that on the surface at the same local time. From this evidence it is concluded that the source of both Dst and DS in low latitudes are external to the satellite altitudes (410-1510 km). The disturbance observed near the dusk meridian commenced several hours sooner than that observed near the dawn meridian, reached its maximum intensity in 18 hours and then decayed in another 18 hours to the level seen on the dawn meridian.

Polar ionospheric currents were detected more than 1.5 hours before the storm's main phase. These currents conform to the classical "two celled" model which includes a concentrated eastward current in the evening local time sector and a concentrated westward current in the morning local time sector. The evening currents first appear at $L = 7.5$ and smoothly shift to $L = 4.3$ at the time of maximum Dst. The morning currents first appear at $L = 7.9$ and subsequently shift to $L = 5.3$. The L location of the morning currents is always greater than that of the evening currents. These currents decrease at least by an order of magnitude at the same time as the transition from asymmetric to symmetric inflation is seen at low latitude.

C-07 (Anderson, Neher, Ionization Comparison over the Polar Region)

Anderson, H. R., and J. E. McCoy, "Results from POGO Ion Chamber Experiment," presented at the AGU Meeting, Washington, D. C., Vol. 48, No., 1, 162, Mar. 1967.

ABSTRACT: The POGO spacecraft was launched on October 14, 1965, into a polar orbit with an inclination of $\sim 87^\circ$, and apogee and perigee altitudes of ~ 1520 km and ~ 430 km. The integrating ionization chamber on POGO employs a quartz fiber electrometer to measure the ion current collected from the argon filling gas. The chamber's wall consists of 0.2 g/cm^2 of steel, so that

protons with $E > 10$ Mev and electrons with $E > 1$ Mev can penetrate to the gas. Data were received, when power was available, from October 14, 1965, to April 3, 1966, and the first 10% of it has been examined. All the data were obtained near the dawn or evening terminator. We find that the high latitude boundary of trapping (at which the ionization falls to ~ 10 times the galactic cosmic-ray level) occurs at an invariant latitude $\Lambda 68.5^\circ$ – 71.5° . In 12% of the passes a spike of intensity was observed, at $\Lambda = 64^\circ$ – 69° , between the boundary and peak of the outer zones. The spikes are observed on successive passes through this latitude in both hemispheres and apparently persist for up to 100 min. These phenomena and the observed increases of ionization above the galactic cosmic-ray level will be described in detail.

Anderson, H. R., L. G. Despain, and H. V. Neher, "Response to Environment and Radiation of an Ionization Chamber and Matched Geiger Tube Used on Spacecraft," *Nuclear Instruments and Methods*, 47, 1-G, 1967.

C-09 (Webber, Cerenkov Detector Galactic and Solar Cosmic Rays)

Bingham, R. G., D. Sawyer, and W. R. Webber, "POGO Satellite and Balloon Measurements of the Relative Spectra of Cosmic-Ray Protons and Helium Nuclei between 0.3 and 15 bv Rigidity," presented at the April 1966 AGU Meeting, Washington, D. C.

ABSTRACT: The spectrum of primary protons and helium nuclei has been measured with a modified Cerenkov-scintillation telescope of the POGO satellite. The measurements cover a two-week period in October 1965 just after the satellite was launched but before severe power limitations restricted the operation of experiments. The energy range is from 50 Mev/nucleon to > 5 bev/nucleon, the higher energies being obtained on a number of equatorial passes underneath the radiational belts using the Earth's field as a magnetic spectrometer. The features of the latitude 'knee,' using data from this telescope as well as an omnidirectional scintillation counter, will also be presented, along with measurements of the intensity and latitude dependence of the radiation. The behavior of the latitude curve at latitudes above the 'knee' will also be examined. The influence on the latitude curve of re-entrant albedo particles, both electrons and protons, and the importance of a primary electron component of low energies incident over the polar regions will also be discussed.

Bingham, R. G., W. C. Erickson, R. L. Howard, J. Lezniak, D. M. Sawyer, and W. R. Webber, "Two Satellite-Borne Cosmic Radiation Detectors," *IEEE Transactions on Nuclear Science*, NS-13, 478, 1966, University of Minnesota Technical Report CR-84, October 1965.

ABSTRACT: Cosmic radiation telescopes constructed at the University of Minnesota will be flown on the Polar Orbiting Geophysical Observatories, POGO C and D, and on the Pioneer Deep Space Probes C and D. These experiments are designed to measure the differential energy spectra of protons, helium nuclei and heavy nuclei up to a charge $Z = 14$ in the range 1.0 to 1200 MeV per nucleon. The POGO telescope utilizes a combination of scintillation and Cerenkov counters together with a semiconductor detector. Use of the thresholds in the geomagnetic field extends the energy range for protons to 30 BeV. A Geiger tube, four lithium-drifted silicon detectors, and a Cerenkov counter comprise the Pioneer telescope.

Sawyer, D. M., J. F. Ormes, W. R. Webber, and R. G. Bingham, "Direct Measurements of Geomagnetic Cut-Offs for Cosmic Ray Particles in the Latitude Range $\lambda = 45^\circ$ – 70° Using Balloons and Satellites," presented at the 10th International Conf. on Cosmic Rays, Calgary, Canada, June 1967, to be published in *Can. J. Physics*.

ABSTRACT: The quiet time cut-off rigidities for cosmic ray particles have been directly measured in 1963-1965 at 6 locations in North America with geomagnetic latitudes (λ) between 45° and 70° using balloon borne Cerenkov-scintillation counters. An identical counter with 0.1 of the area has been carried aloft in a polar orbiting satellite from which it has been possible to determine the cut-offs for protons in four intervals between $L = 3$ and $L = 5$. The measured cut-offs are consistently below those expected on the basis of detailed orbit calculations based on the surface field of the earth (Shea and Smart, 1967). These differences amount to a $\simeq 7\%$ reduction at $\lambda = 45^\circ$, increasing to $\simeq 25\%$ at 60° . At 70° the cut-off is apparently $< 12\%$ of the expected internal field value of 190 MV at 2100 hours local time.

A limit to the amount of reduction produced by a ring current within the magnetosphere can be set from the data at latitudes $< 60^\circ$. The most reasonable value for the magnetic moment of this ring current is $0.08 M_e$. The situation at latitudes $> 60^\circ$ is characterized by large diurnal changes in the cut-offs.

C-12 (Blamont, Photometer, Airglow Study)

Pacquet, J., "Methods of Data Reduction for the OPEP Airglow Photometer on OGO-II," GSFC X-613-67-218, Preprint.

ABSTRACT: A brief description is given of the methods used in the reduction of the data from the OPEP airglow photometer on OGO-II. For selected portions of the data, computers have been used to apply instrumental corrections, to reduce an oscillatory component dependent on the position of the OPEP container, and to solve a system of linear equations to compute a vertical emission profile from the observed horizon profiles.

Reed, E. I., and J. E. Blamont, "Some Results Concerning the Principal Airglow Lines as Measured from the OGO-II Satellite," presented at the May 1966 Space Science Symposium COSPAR, Vienna, Austria, *Space Res. VII*, 337, 1967, North-Holland Pub. Co., Amsterdam, also GSFC X-613-66-190, Preprint.

ABSTRACT: Two photometers on the OGO-II spacecraft (launched October 14, 1965, 420 km perigee, 1520 km apogee, 87.4° inclination) scanned the airglow horizon through a filter centered at 6300A, the nadir airglow at 6300A, 6225A, 5890A, 5577A, 3914A, and 2630A, and the zenith airglow at 6300A. During its less than 10 days of stabilized operation approximately an hour of data were obtained while in the earth's shadow. The nadir measurements observed the blue enhancement at twilight, several aurorae, and typical nighttime airglow. The horizon scanning photometer observed the two airglow layers: a thick one generally above 200 km attributed to the 6300A line of atomic oxygen and a thin layer centered between 75 and 105 km attributed to the OH emissions which fall within the 40A wide passband of the interference filter. The maximum emission of the 6300A Line occurred generally between 200 and 300 km altitude with values of 1 to $25 \text{ photons cm}^{-3} \text{ sec}^{-1}$ at night and about a factor of 10 greater in the twilight.

Reed, E. I., W. B. Fowler, C. W. Aitken, and J. F. Brun, "Some Effects of MeV Electrons on the OGO-II (POGO) Airglow Photometers," March 1967, GSFC X-613-67-132, Preprint.

ABSTRACT: After noting the high levels of background current in the Main Body Airglow Photometer on OGO-II, a Polar Orbiting Geophysical Observatory, a series of laboratory tests were made to indicate the sources of interference and methods of prevention. Tests with 2.6 MeV electrons confirmed that such electrons in space could account for the observed signals. Other tests were made which (1) showed that the most sensitive portion of the photometer was the cathode-window combination in the photomultiplier, (2) indicated the effectiveness of various methods of shielding, and (3) studied the presence and decay time of radiation-induced phosphorescence. Further laboratory tests confirmed that a similar OPEP photometer on the same satellite, with a different photomultiplier, a more limited spectral range, and greater shielding, was relatively insensitive to the same environment.

C-15 (Jones, Massenfilter Mass Spectrometer, Neutral Particle and Ion Composition)

Hinton, B. B., R. J. Leite, and C. J. Mason, "Neutral Atmospheric Composition Measurements between 100 and 290 Kilometers," paper to be presented at the 1968 Spring Meeting of the AGU.

ABSTRACT: Composition measurements of the neutral atmosphere over the altitude range of 105 km to 291 km (peak) were made on August 8, 1967 shortly after sunrise at White Sands, N. M. on Aerobee NASA 4.207. The data were obtained with a quadrupole mass spectrometer essentially identical to those presently in orbit on OGO-II and OGO-IV. The rocket instrument sweeps the mass range 0-50 amu in approximately 0.6 seconds; its sensitivity is 10^{-4} amp/torr with a resolution of 20. The spectrometer was evacuated prior to flight and an ejectable cover removed at 84

km. The masses observed were 44, 40, 32, 28, 18, 16, 14, and 4. Of particular interest is the observed variation of mass 14, tentatively identified as atomic nitrogen, with altitude; it appears to be in general agreement with recent predictions by Ghosh of the distribution and lifetime of N between 100 and 280 km. Preliminary analysis indicates that the concentrations of the various atmospheric species are representative of those characterizing a quiescent atmosphere.

C-16 (Taylor, Bennett Ion Spectrometer, Positive Ion Study)

Taylor, H., Jr., H. Brinton, and L. Muenz, "First Results from OGO-C Ion Composition Experiment," presented at the April 1966 AGU Meeting, Washington, D. C.

ABSTRACT: Positive ion composition data obtained from the RF spectrometer experiment aboard OGO-C are presented, covering the period October 4 to October 24, 1965. In the near polar orbit, over an altitude range of 400 to 1500 kilometers, the predominant ions observed were H^+ , He^+ , and O^+ . The range of density variation determined for these ions which is of the order of 10 to 10^5 ions/cm³ indicates the combined influences of altitude and latitude on the ion density distributions.

Taylor, H. A., Jr., H. C. Brinton, M. W. Pharo, III, and N. K. Rahman, "Thermal Ions in the Exosphere; Evidence of Solar and Geomagnetic Control," submitted to *J. Geophys. Res.*, 1968.

ABSTRACT: Direct measurements of a pronounced latitudinal variation in the exospheric ion composition have been obtained from the RF ion spectrometer experiment aboard the Polar Orbiting Geophysical Observatory (OGO-II). Measurements of thermal positive ions obtained in a nearly polar dawn-dusk orbit during mid-October, 1965, show that in the altitude range of 415 to 1525 kilometers the ionosphere is composed of the primary ions O^+ and H^+ and the secondary ions N^+ and He^+ . Consistent with this period of low solar activity He^+ is at all altitudes a minor ion, relative to H^+ . Evidence of both solar and geomagnetic control of the ion distributions is extended by extrapolating the data to both (1) a constant 1000 kilometer reference level and (2) the dipole equator, applying field aligned chemical and diffusive equilibrium theory. At 1000 kilometers O^+ dominates in both the northern and southern polar ionospheres, yielding at lower latitudes to H^+ which dominates at the equator. The resultant mean ion mass distribution which gives about 14 to 15 AMU at the poles and 2 to 4 AMU at the equator is generally consistent with theory and other measurements. The latitudinal asymmetry in the distributions of O^+ and N^+ reflect the seasonal influence of solar control, while the greater symmetry in the distributions of H^+ and He^+ reveals the strong influence of solar-geomagnetic control of the light ions. The high latitude ionosphere is marked by two dominant features: (1) a persistent, major trough in $n(H^+)$ and $n(He^+)$, where $n(H^+)$ drops to about 10^2 ions/cm³ near 60 degrees dipole and (2) a variable poleward peak in which the total ion concentration, N_i , approaches 10^4 ions/cm³ near 80 degrees dipole. The pronounced light ion trough, which correlates with the whistler cutoff, is believed to mark the high latitude boundary of the thermal plasma which diffuses upward along closed field lines to populate the plasmasphere. Poleward of the trough the strong fluctuations in the composition and the variability of the amplitude and position of the ionization peak suggest that the polar exosphere is decoupled from the plasmasphere and is probably linked with the solar wind-magnetospheric tail system. Comparison of the extrapolated equatorial N_i profile with thermal ion distributions measured directly in the magnetosphere further supports this observation.

C-18 (Nilsson, Micrometeorite Detectors)

Nilsson, C. S., "Some Doubts about the Earth's Dust Cloud," *Science*, 153, 1242-1246, Sept. 9, 1966.

ABSTRACT: Considerable doubt is cast on the validity of past satellite measurements of micrometeoroid fluxes in which piezoelectric microphones have been used as detectors. Data have been obtained from satellite and laboratory experiments which show that the microphone crystals emit noise when subject to slowly varying temperatures. The rate of noise is consistent with past flight data which have previously been interpreted on the basis of micrometeoroid impacts. These measurements have given rise to the theory that the earth is surrounded by a cloud of dust, although no satisfactory mechanism has yet been found to explain this apparent phenomenon. On the basis of

the results reported here, it now appears that whether or not a concentration of dust exists in the vicinity of the earth, the data from satellite microphone measurements should not be used to support such a hypothesis.

Nilsson, C. S., and R. B. Southworth, "The Flux of Meteors and Micrometeoroids in Neighborhood of the Earth," paper presented at the IAU Meeting, Tatrausha Lomnica, Czechoslovakia, September 1967, to be published as a Smithsonian special report.

C-20 (Hinteregger, Solar XUV Spectrophotometers)

Bedo, D. E., and H. E. Hinteregger, "Collimating Grating Monochromators for the Vacuum Ultraviolet," *Jap. J. Appl. Phys.*, 4, Suppl. 1, 473-477, 1965.

ABSTRACT: A non-focusing, grazing incidence monochromator which utilizes planar gratings and collimating slit systems is described. Such an instrument is capable of moderate spectral resolution in the vacuum ultraviolet and allows for relatively simple scanning mechanisms. Monochromators of this type have been built for laboratory studies and for incorporation in a satellite-borne experiment for monitoring solar intensities in the extreme ultraviolet. Measurements made on rare gas spectra indicate approximate agreement between computed and observed instrumental line widths.

Hills, R. S., "XUV Spectrophotometer for OGO-C&D Satellites," Section 3, Final Report, AFCRL-65-417, March 1965.

ABSTRACT: Report describes the development, construction and testing of all electronic components and circuitry of the OGO-C and OGO-D XUV spectrophotometer, including ground support equipment. Photographs and schematic diagrams are presented.

Sullivan, J. D., J. F. McGrath, and W. J. Thorburn, "XUV Spectrophotometer for POGO Satellites," Section 4, Final Report, Contract AF19 (604)-7496, Comstock and Wescott, Inc., Cambridge, Mass., AFCRL-64-773, August 1964. N 65-14508.

ABSTRACT: The design and development of a spectrophotometer capable of measuring radiation in the soft X-ray and extreme ultraviolet region (euv radiation) is reported. The spectrometer consists of three sections: (a) the collimator drive, position encoder, and the high voltage power supplies (b) the entrance aperture, gratings collimator, and photomultiplier; and (c) the electronics circuitry. The operation, testing, and calibration of the instrument are described, and drawings and photographs are presented.

OGO-II TECHNICAL PAPERS

Blair, W. E., and B. P. Ficklin, "Summary of Digital Data-Processing Systems for the OGO SU/SRI Very-Low Frequency Experiments," Stanford Radioscience Laboratory Summary Report, July 1967.

ABSTRACT: This report summarizes the computer digital data-processing techniques for the Stanford University/Stanford Research Institute (SU/SRI) very-low-frequency (VLF) radio noise and propagation experiments aboard the OGO satellites. Specifically, the processing system outputs for the VLF experiments aboard OGO-I (A-17), OGO-II (C-02), and OGO-III (B-17) are briefly described. These outputs are contiguous 16-mm cine films on which the data are plotted and pertinent satellite and geophysical parameters are listed. The cine films are described, and the advantages of the system for compacting, scanning, accessing, and analyzing the data are stated.

Caughy, R. T., and J. J. Quann, "Data Processing Plan for Polar Orbiting Geophysical Observatory (OGO-C)," Data Processing Branch, August 1965, GSFC X-564-65-329, Preprint.

ABSTRACT: The OGO-C Spacecraft, depicted in Figure 1, will carry into a polar and nearly circular orbit about the earth, a large number of varied geophysical experiments. A greater understanding of the earth, and of earth-sun relationships will be obtained from these. OGO-C experiments will supply data from the equatorial latitudes to the poles, and while traversing the latter regions will provide observation of such phenomena as auroras and low energy solar particles. OGO-C, with its on-board magnetometer experiments, will also serve as a prime support of the United States commitment to the World Magnetic Survey.

OGO-C will be launched by a TAT-Agena vehicle from the Pacific Missile Range into a near polar orbit having perigee and apogee of 180 and 500 nautical miles respectively. It will have an orbital period of 97.31 minutes and an inclination of 86 degrees. Figure 3 shows the subsatellite plot for orbital revolutions 000 thru 005.

The maximum lifetime anticipated for OGO-C is one year.

Farthing, W. H., and W. C. Folz, "A Rubidium Vapor Magnetometer for Near Earth Orbiting Spacecraft," GSFC X-612-66-575.

ABSTRACT: This paper describes the instrumentation and in-flight performance of the rubidium vapor magnetometers being flown by the National Aeronautics and Space Administration on the POGO satellites. An optically pumped, self-oscillating rubidium magnetometer was selected as being most compatible with the objectives of the study and with the spacecraft capabilities. A four absorption cell configuration is used to reduce the effect of the null zones inherent in these instruments and to obtain accuracies compatible with the scientific objectives of the program. Scalar magnetic field data is obtained in both digital (PCM) and analog (frequency multiplex) form. Instrument performance parameters are monitored through both main frame and subcommutated PCM data.

The first instrument orbited was aboard OGO-II which was launched on October 14, 1965. This instrument has returned a large quantity of data, and is still operating when sufficient spacecraft power is available. The accuracy of the data is determined, apart from orbit accuracy, by spurious phase shifts within the instrument. These arise from such sources as optical axis misalignment, electronic non-linearities and frequency dependence, and propagation delay over the long cables connecting sensor and electronics. The magnitude of the resulting error is inversely proportional to the phase slope of the dual cell absorption line. The total effect in the POGO instrument of these sources of error is an accuracy of better than 1.5 gammas over the entire instrument range of 15,000 to 64,000 gammas.

Ferris, A. G., and W. E. Scull, "Orbiting Geophysical Observatory OGO-C Operations Plan 10-65," August 1965, GSFC X-513-65-346, Preprint.

ABSTRACT: The primary objective of the Orbiting Geophysical Observatory (OGO) program is to conduct large numbers of significant, diversified geophysical experiments for obtaining a better understanding of the earth-sun relationships and the earth as a planet.

The secondary objective of the program is the development and operation of a standardized observatory-type oriented spacecraft, consisting of a basic structure and subsystems design which can be used repeatedly to carry large numbers of easily integrated scientific experiments in a wide variety of orbits.

Fitzwater, D. R., E. H. Hietbrink, M. M. Ledet, D. E. McFarland, and C. E. Runge, "POGO PSAG Manual," May 1964. N64-30757.

ABSTRACT: The problem considered in this paper is the design and structure of the POGO monitor. The programs comprising the monitor and the necessary modifications to the compiler systems tape are discussed. Flow charts accompany the writeups. Author

Fitzwater, D. R., E. H. Hietbrink, M. M. Ledet, D. E. McFarland, and C. E. Runge, "POGO Reference Manual," November 1965. N64-13388.

ABSTRACT: This programmers' manual for POGO supplies the necessary background information for the use of the various system functions as well as program descriptions for each system function, and examples of their use. Author

Hughes Aircraft Co., "Solar Electric Propelled Spacecraft. Capabilities Study," Final Report, 111, June 1963. N63-22586.

ABSTRACT: This report presents preliminary system designs of two solar-electric-propelled spacecraft, one utilizing an electrostatic engine (ion), and the other utilizing an electrothermal engine (resisto-jet), both of which are capable of accomplishing the Polar Orbiting Geophysical Observatory (POGO) scientific mission. The systems presented used the Thor-Agena B launch vehicle, utilize solar cells for primary power, and have three-axis cold gas attitude-control systems for the spacecraft proper, and independent power gimbal-drive altitude-control systems for the scientific packages. An onboard high-density magnetic tape storage system is provided with a data storage capacity in excess of 11,000,000 bits. For equal power levels, the electrothermal engine spacecraft is superior to the electrostatic engine spacecraft from both an orbit transfer time and maximum altitude standpoint. The scientific mission capability attainable, pertaining to altitude and payload, is significantly affected by choice of engine type. The general arrangement is also greatly affected by engine type, which in turn has a predominant effect on solar panel deployment method and payload orientation control. Author

Langel, R. A., "A Representation of the Perigee Motion of a Satellite as a Function of Local Time," NASA GSFC Technical Abstracts, 5, No. 1, Jan.-Mar. 1967. X-612-67-34.

ABSTRACT: Expressions are developed for computing the local time and latitude of the perigee point on an elliptical (earth centered) orbit. The expressions are functions only of the instantaneous orbital elements. A method of using these expressions to obtain the local time and latitude of perigee at any time is described. These results are applied to the OGO-II satellite where the accuracy over a nine-month span was found to be within one degree in both latitude and local time.

Langel, R. A., "Processing of the Total Field Magnetometer Data from the OGO-II Satellite," GSFC X-612-67-272.

Montgomery, H., and C. Herron, "Shades of POGO," November 1964, GSFC X-640-64-349, Preprint.

ABSTRACT: The Orbiting Geophysical Observatory (OGO) consists of a main box, the solar array, and the orbital plane experiment package (OPEP). Experiments may be appended to any of the three main component parts either directly or on booms. As many as fifty experiment packages may be carried on the OGO spacecraft. The solar array and the OPEP may rotate relative to the main box. The main box and the solar array are considered as casting shadows and carrying experiments; the OPEP is considered only as carrying experiments. Heat inputs include direct solar, reflected solar, and Earth emitted heat flux. If the experiment is shielded from the Sun by the Earth, the main box, or the solar array, the solar input to that particular experiment is set to zero. If an experiment is in the eclipse of the Earth, the reflected solar (as well as the direct solar) heat input is set to zero. However, the effects of shadowing of an experiment from the Earth by the main box or by the solar array is not considered in the computation of the solar reflected or Earth emitted heat inputs to that particular experiment. Shadow data are presented for the S-50 (POGO) for a launch date of March 14, 1965, at 14.5 hours U. T. The heat input data are for an EPOCH time of September 12, 1965, at 1.5 hours U. T.

NASA GSFC, "Summaries of Category I Proposals for S-50 (POGO) Experiments," September, 1962, GSFC X-623-62-145, Preprint.

NASA News Release Press Kit 65-314, "NASA to Launch Second Orbiting Geophysical Observatory," October 12, 1965.

OGO Project Office, GSFC, "OGO-C Experiment Manual," GSFC OGO Operations, May 1966.

Operations Center Branch, GSFC, "NASA-GSFC Operations Summary for Orbiting Geophysical Observatory OGO-C," October 1965, GSFC X-512-65-412, Preprint.

ABSTRACT: The Orbiting Geophysical Observatory (OGO-C) is the second in a series of spacecraft which NASA will launch to accomplish the program objectives. The OGO-C will carry twenty scientific experiments over the polar region where a number of special phenomena, such as auroras and low energy solar particles may be observed. These experiments will serve to provide data over the complete range of latitudes extending from equatorial to polar regions.

A Thrust Augmented Thor (TAT)/Agena D two stage launch vehicle (Figure 1-1) will be utilized to place the OGO-C spacecraft into a precise polar orbit. The launch will be performed at the Air Force Western Test Range (WTR), Vandenberg Air Force Base, California. The spacecraft will be launched in a southeast direction from the range.

Stations of the GSFC worldwide Spacing Tracking and Data Acquisition Network (STADAN) will track, command, and acquire telemetry data from orbit injection until termination of the useful lifetime of the spacecraft. Post Launch monitoring and operational control of the spacecraft will be conducted from the GSFC OGO Operations Control Center. Processing and reduction of the telemetered data that is received will be accomplished by the GSFC Information Processing Division.

Russey, R. E., "Vehicle System Integration Requirements and Restraints Document for the Orbiting Geophysical Observatory (S-49, S-50) Spacecraft," GSFC Spacecraft Systems Branch, January, 1962.

ABSTRACT: This document is concerned with the technical requirements and restraints which the NASA satellite missions, Orbiting Geophysical Observatories, designated S-49 and S-50, impose on their respective launch vehicles. It is intended that this document define all technical requirements within its scope.

Spacecraft Integration and Sounding Rocket Division, GSFC, "POGO Data System Reference Manual MOD III," January 1966, GSFC X-722-66-6, Preprint.

ABSTRACT: The OGO-C (S-50) Data System MOD III is a collection of programs and subroutines used to analyze PCM telemetry data from the S-50 experiments and spacecraft during subsystem and observatory level tests.

The programs have been designed to run in any SDS 910 or 920 computer system configured as shown by GSFC Drawing No. S50-1005-601 titled "POGO 920/910 Computer System Interconnect Diagram."

The S-50 Data System MOD III includes both utility and experiment programs.

Stewart, D. J., and J. J. Fleming, "Orbit Determination Plan for the Satellite OGO-C," GSFC X-547-65-309, Preprint.

ABSTRACT: The primary objective of the Polar Orbiting Geophysical Observatory (OGO-C) Satellite is to conduct large numbers of significant, diversified geophysical experiments for obtaining a better understanding of the earth-sun relationships and the earth as a planet. The secondary objective of the program is the development and operation of a standardized observatory-type oriented spacecraft, consisting of a basic structure and sub-systems design which can be used repeatedly to carry large numbers of easily integrated scientific experiments in a wide variety of orbits. As a design objective for the standardized spacecraft, it is desired that the spacecraft be capable of operation for a period of one year, during which the orientation of portions of the spacecraft toward the sun, the earth and in the orbital plane can be accomplished.

The satellite is to be launched to the southeast from the Western Test Range. Nominal values for the principal elements are as follows:

Period, minutes	97	Apogee height, s.m.	576
Perigee height, s.m.	207	Apogee height, km.	926
Perigee height, km.	333	Inclination, degrees	86

The satellite will be separated from the second stage about 9 minutes after lift-off.

TRW Systems, Inc., NASA Contract NAS 5-899, Report No. 2324-6002-RU000 Operation Summary Report OGO-II, October 1965.

ABSTRACT: This report is an Operations Summary for OGO-II covering the period 14 October 1965 through 24 October 1965. Performance characteristics for the Observatory's major subsystems are herein discussed along with a description of all significant events experienced during the launch and in-orbit phases of the operation.

The OGO-II Operations Summary Report is submitted to the Goddard Space Flight Center under Contract NAS 5-899.

TRW/STL Experiment Data Book, OGO C and D, for the Orbiting Geophysical Observatory Program. Volumes 1 and 2, October 28, 1966.

Wiggins, E. T., "Operations Summary Report OGO-II," Report No. 2338-6010-RU000, June, 1966.

OGO-III DESCRIPTION OF EXPERIMENTS

B-01 SOLAR COSMIC-RAYS, Dr. Kinsey A. Anderson, UCLA

This experiment consists of scintillation type detectors to measure the form and time variations of the energy spectrum from a few Mev up to 90 Mev, investigate spatial inhomogeneities of the solar-proton flux upon their arrival at the earth, search for proton fluxes attributable to flares on the back side of the sun, monitor X-rays from the sun, measure the flux and energy of photons which arise in proton-producing flares, and measure protons in the galactic cosmic radiation during the approach to solar minimum.

B-02 ELECTROSTATIC PLASMA ANALYZER, Dr. J. H. Wolfe, ARC

The findings of this experiment will further understanding of the lower energy (a few to a few thousand electron volts) particles and their relationship to other geophysical, solar, and cosmic phenomena. The distribution of plasma particles is particularly important in understanding the distributions of magnetic fields in space.

B-03 PLASMA FARADAY CUP, Dr. H. J. Bridge, MIT

This experiment is concerned with properties of the solar plasma in the tens of thousands of electron volts range, and their influence on the earth's magnetosphere. Scientific objectives include measurements of the following quantities: proton flux, proton-energy spectrum, and direction of the flux, as well as temporal and spatial variations of these quantities, and correlation of the above data with measurements of the magnetic field.

B-04 POSITRON SEARCH AND GAMMA-RAY SPECTRUM, Dr. T. L. Cline, GSFC, and Dr. E. W. Hones, Jr., IDA

This experiment will investigate the possible existence of low-energy positrons trapped in a permanent or transitory manner in the radiation belts, and the possible arrival of low-energy solar or interplanetary positrons at the edge of the earth's magnetic field. This experiment will be able to measure, over a wide dynamic range, the flux of gamma rays in the energy range from 30 kev to 1.2 Mev.

B-05 TRAPPED RADIATION, SCINTILLATION COUNTER, Dr. A. Konradi, GSFC

This experiment will provide further studies of the temporal and spatial variations of the particle intensities, pitch-angle distribution, and energy spectra of electrons and protons, and will answer questions such as: particle lifetimes, processes by which trapped particles are lost, and the sources and accelerating mechanisms of the trapped particles.

B-06 COSMIC-RAY ISOTOPIC ABUNDANCE, Dr. F. B. McDonald, GSFC

A cosmic-ray telescope will analyze the charge and energy spectrum of the primary cosmic radiation to assist in determining the amount of interstellar material through which primary cosmic rays have passed between their source and the vicinity of the earth, to study the modulation mechanisms which act on the cosmic rays, and to study the charge and energy spectra of cosmic rays produced by the sun.

LOW ENERGY PROTON ANALYZER, Dr. D. S. Evans, GSFC

The absolute intensity and energy spectrum of protons in the little-explored energy range of 5 kev to 100 kev will be measured to determine both the spatial structure, from $L = 2$ to beyond the magnetospheric boundary, and the temporal variation of these particles.

B-07 COSMIC-RAY SPECTRA AND FLUXES, Dr. J. A. Simpson, U. of Chicago

This experiment will assist in the search for the acceleration mechanisms acting on cosmic rays and solar particles, and will study the electro-dynamic processes of solar origin which lead to the modulation of the galactic-ray flux, such as the 11-year cycle, the Forbush decreases, and the 27-day variation.

B-08 LOW ENERGY ELECTRON AND PROTON DETECTOR, Dr. J. A. Van Allen, SUI

This experiment will study the spatial and temporal distribution of low energy electrons and protons (0.10 to 50 kev) within and outside the earth's magnetosphere with special interest in the wings and tail of the magnetosphere. Measurements will be made with a cylindrical electrostatic analyzer and thin window Geiger-Mueller tubes.

B-09 TRAPPED RADIATION, ELECTRON SPECTROMETER, Dr. J. R. Winckler, and Dr. R. L. Arnoldy, U. of Minn.

This experiment employs two primary detector systems. A swept magnetic-field electron spectrometer will make a precise measurement of the electron-energy spectrum in the range 50 kev to 4 Mev. An ionization chamber and G-M counter will assist in the determination of the electron, proton, and X-ray fluxes. The experiment will assist in the study of the injection, trapping, and loss mechanisms acting in the earth's radiation belts.

B-10 TRIAXIAL SEARCH COIL MAGNETOMETER, Dr. E. J. Smith, JPL, and Dr. R. E. Holzer, UCLA

The objectives of this experiment are to investigate the nature of extremely low-frequency variations (0.01 to 1000 cps) in the terrestrial geomagnetic field, in the interplanetary field, and in the vicinity of the interface between them and to investigate the relationship between the fluctuations in these three regions of space and the simultaneous variations at the earth's surface.

B-11 RUBIDIUM-VAPOR AND FLUXGATE MAGNETOMETER, Dr. J. P. Heppner, GSFC

A combination of component fluxgate sensors and a rubidium-vapor magnetometer is intended to provide comprehensive field measurements with a known absolute accuracy. Objectives of this experiment are to accurately measure the interaction of solar and geomagnetic field phenomena, to measure the local field sources such as ring currents, to study the rapid field fluctuations with frequency ranges covering at least four orders of magnitude, and to provide charts and mathematical descriptions for the International World Magnetic Field Survey.

B-12 SPHERICAL ION AND ELECTRON TRAP, Dr. R. C. Sagalyn, AFCRL

This experiment uses a spherical electrostatic analyzer to measure the concentration and energy distribution of charged particles having thermal energies.

B-13 PLANAR ION AND ELECTRON TRAP, E. C. Whipple, ESSA

This experiment will obtain the density and energy distribution of charged particles in the low-energy or thermal ranges in the transition region between the ionosphere and interplanetary space, and in interplanetary space, which is characterized by low particle densities.

B-14 RADIO PROPAGATION, Dr. J. K. Hargreaves, ESSA

This experiment will make accurate measurements of the electron density along the line-of-sight by determination of the Faraday rotations of two harmonically related, linearly polarized waves. Ground stations will be able to measure the magnitude of large-scale horizontal irregularities in the electron distribution of the ionosphere and exosphere.

B-15 ATMOSPHERIC MASS SPECTRUM, H. A. Taylor, Jr., GSFC

This experiment will obtain direct measurements of positive-ion composition in the mass range 1-50 AMU through the EGO orbit by the use of a Bennett RF mass spectrometer.

B-16 INTERPLANETARY DUST PARTICLES, Prof. J. L. Bohn, Temple U.

This experiment will establish the velocity and mass distributions for interplanetary dust particles of micron size. The findings of this experiment will extend the mass-distribution curve out to the radiation-pressure limit, and measure the fluctuations in velocity distribution, mass distribution, and spatial densities.

B-17 VLF NOISE AND PROPAGATION, Dr. R. A. Helliwell, Stanford U.

This experiment will increase the overall understanding of the VLF phenomena in the earth's magnetosphere, such as the terrestrial noise produced below a height of 70 km (atmospherics due to lightning noise generated within the earth's ionosphere and magnetosphere), VLF emissions produced by incoming solar particles, and cosmic noise of entirely extraterrestrial origin such as solar and planetary noise. The frequency range to be covered is 200 to 100,000 cps.

B-18 RADIO ASTRONOMY, Prof. F. T. Haddock, U. of Mich.

The prime objective of this experiment is to measure the dynamic radio spectrum of solar radio-noise bursts. The frequency drift rate, frequency bandwidth, and duration of fast-drift solar bursts will be observed. This experiment may also observe radio bursts from the planet Jupiter. Additional observations to be made are: cosmic-noise intensity, ionospheric electron densities (50 to 500 electrons/cm³), atmospherics, auroral noise from the earth to observatory, and radio noise generated in the terrestrial ionosphere and in interplanetary plasmas. The investigations will cover the frequency ranges from 200 to 400 kc and 2 to 4 Mc.

B-19 GEOCORONAL LYMAN-ALPHA SCATTERING, Dr. P. M. Mange, NRL

The lyman-alpha glow in the night sky probably originates from either a geocorona or the interplanetary medium. To distinguish the relative contributions of these two sources, it is necessary to make measurements from great altitudes which will permit separation of the sources of the resonantly scattered light.

B-20 GEGENSCHIEIN PHOTOMETRY, Dr. C. L. Wolff, GSFC, and Dr. S. P. Wyatt, U. of Illinois

The question as to where the Gegenschein (counterglow) originates in space has defied solution by ground observers for nearly two centuries, and is not likely to be solved until an observation is made sufficiently far from the earth to show a parallax. This experiment will study the antisolar direction and nature of the scattering centers which produce the Gegenschein.

OGO-III EXPERIMENTS

B-01 (Anderson, Solar Cosmic-Rays)

Kahler, S., K. A. Anderson, and J. H. Primbsch, "Anisotropies of Mev Protons from the Solar Flare of August 28, 1966, and the Geomagnetic Storm of August 29, 1966," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 178, Mar. 1967.

ABSTRACT: The directional properties of the University of California 2-100 Mev proton detector on the OGO-III satellite were used to study the anisotropies of Mev protons from the solar flare of August 28, 1966, and the sudden commencement which occurred at 1314 UT on August 29. Mev proton fluxes following the sudden commencement were greater than 2000 particles/cm²/sec. Due to the spacecraft spin, the detector traced out a cone of half-angle 52°. Anisotropies of greater than 4 to 1 were seen in the protons following the sudden commencement. Deviations from azimuthal symmetry were present at certain times. Since 32-channel pulse height analysis was employed in the experiment, the anisotropies of each of the lowest channels could be examined separately. A preliminary analysis shows no energy dependence in the anisotropies observed. Comparison of the data is made with a recent model by Roelof for the diffusion of solar protons by a 1-dimensional 'Browning motion' in the interplanetary field. The large observed anisotropies suggest that not enough scattering by the magnetic irregularities has taken place for the pitch angle distribution of the particles to reach a 'relaxed' or asymptotic distribution.

Kahler, S. W., "Observations of 3-10 MeV Protons in Energetic Storm Particle Events," to be presented at the AGU Meeting, Washington, D. C., April, 1968.

ABSTRACT: Observations of three energetic storm particle events were made with the University of California scintillation counter on the OGO-III spacecraft. These events occurred on August 29 and September 14, 1966 and February 15, 1967. In each of these events it was observed that the energy spectrum of the 3-10 MeV protons grew softer after the SC storm, but later it became harder. In the case of the August 29 event the softest spectrum and the largest fluxes occur closely in time. These observations are interpreted in terms of a model of particle diffusion in the solar corona by Reid. It is hypothesized that the plasma cloud which causes the SC connects the earth to the flare region via the interplanetary magnetic field. No evidence is found for either interplanetary trapping or interplanetary acceleration of the energetic storm protons.

Kahler, S. W., "Propagation of Solar Protons," Ph. D. Dissertation, Physics Department, University of California, Berkeley, January 1968.

ABSTRACT: Data from a scintillation counter experiment on the OGO-III spacecraft are used to analyze twelve energetic ($3 < E < 32$ MeV) solar proton events from June, 1966 to February, 1967. The OGO-III spacecraft, the performance of the experiment and methods of data analysis are discussed. The proton events presented here have been divided into four groups, each of which has well defined properties. The *diffusive event* follows an impulsive injection of particles at the sun and decays exponentially in time. The onset phase may be smooth or irregular, but the spectrum grows progressively softer during the decay phase. The *storm particle event* is a low energy event associated with a geomagnetic storm. During this event the spectrum first grows softer, then becomes harder. The *halo structure* is a stream of particles confined to the interplanetary lines of force which connect to the flare region at the sun. *Recurrent proton events* are due to the gradual release of particles from an active region in which a flare has occurred during a previous solar rotation. The two examples reported here showed narrow ($\lesssim 10$ hours) interplanetary spatial confinement. Representative fluxes and modified spectral behavior are presented for these events.

These events are used as a basis for describing a model of a typical solar proton event. The model of coronal diffusion of Reid and Axford is used.

Kahler, S. W., "The Recurrent Proton Events of June 24 and September 27, 1966," to be presented at the AAS Special Meeting on Solar Astronomy, Tucson, Arizona, February, 1968. Abstract to be published in the *Astron. J.*

ABSTRACT: The proton events of June 24 and September 27, 1966 which were observed on the OGO-III and IMP-III satellites appear to be recurrent events from the flares of May 28 and

September 2, 1966 respectively. The two events show several similar features: (1) they were low energy (several MeV) events; (2) the active region believed to be the source was located at a solar longitude of $\sim W35^\circ$; (3) the protons appear to be associated with geomagnetic disturbances; (4) the events are short lived, indicating that they are narrowly collimated in space. The September 27 particles probably recurred again on October 24, since another short lived, low energy ($E > 0.5$ MeV) event was seen on IMP-III. A comparison is made with the flare associated recurrent events seen on Explorer 12 in 1961.

Lin, R. P., S. W. Kahler, and E. C. Roelof, "Solar Flare Injection and Propagation of 0.5-20 MeV Protons and $\gtrsim 45$ keV Electrons Deduced from Large Spatial Flux Gradients Observed on 7-9 July 1966," Space Sciences Laboratory, University of California, July 1967.

ABSTRACT: Simultaneous observations of the 7-9 July 1966 solar particle event by energetic particle detectors on three satellites, IMP-III, OGO-III and Explorer 33 are utilized to show that large spatial gradients are present in the fluxes of 0.5-20 MeV protons and $\gtrsim 45$ keV electrons. The event is divided into three parts: the *ordinary diffusive component*, the *halo* and the *core*. The core co-rotates with the interplanetary field, and therefore it and the surrounding halo are interpreted as spatial features which are connected by the interplanetary magnetic field lines to the vicinity of the flare region. Upper limits to the interplanetary transverse diffusion coefficient at 1 A. U. are derived from the width of the halo for 3-20 MeV protons. These are at least two orders of magnitude less than the parallel diffusion coefficient for the same energy particles.

It is argued that the observed flux variations cannot be explained by an impulsive point source injection for any physically reasonable diffusion model. Instead, since the interplanetary transverse diffusion coefficient is small for these low energy particles, the observed spatial features are interpreted as the projection to 1 A. U. by the interplanetary field lines of an extensive injection profile at the sun. The geometry of the injection mechanism is discussed and it is suggested that some temporary storage of the flare particles occurs in the solar atmosphere.

Lin, R. P., S. W. Kahler and E. C. Roelof, "Solar Flare Injection and Propagation of Low Energy Protons and Electrons in the Event of 7-9 July 1966," *Solar Phys.*, (submitted for publication), 1967.

ABSTRACT: Simultaneous observations of the 7-9 July 1966 solar particle event by energetic particle detectors on three satellites, IMP-III, OGO-III and Explorer 33 are utilized to show that large spatial gradients are present in the fluxes of 0.5-20 MeV protons and $\gtrsim 45$ KeV electrons. The event is divided into three parts: the ordinary diffusive component, the halo and the core. The core co-rotates with the interplanetary field, and therefore it and the surrounding halo are interpreted as spatial features which are connected by the interplanetary magnetic field lines to the vicinity of the flare region. Upper limits to the interplanetary transverse diffusion coefficient for 3-20 MeV protons at 1 A. U. are derived from the width of the halo. These are at least two orders of magnitude less than the parallel diffusion coefficient for the same energy particles.

It is argued that the observed flux variations cannot be explained by an impulsive point source injection for any physically reasonable diffusion model. Instead, since the interplanetary transverse diffusion coefficient is small for these low energy particles, the observed spatial features are interpreted as the projection to 1 A. U. by the interplanetary field lines of an extensive injection profile at the sun. The geometry of the injection mechanism is discussed and it is suggested that some temporary storage of the flare particles occurs near the sun.

B-03 (Bridge, Plasma Faraday Cup)

Vasyliunas, V. M., "Plasma Experiment on OGO-III," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 174, Mar. 1967.

ABSTRACT: OGO-III, launched on June 6, 1966, into a highly eccentric orbit with apogee distance $20.1 R_E$ and initial Sun-Earth-apogee angle of 135° on the dusk side of the Earth, carries 2 modulated Faraday cups that measure, respectively, proton fluxes in 16 energy windows between 50 and 8000 ev, and electron fluxes in 4 energy windows between 40 and 1700 ev. Results on spatial distribution, time variations, and energy spectra of these particles in the magnetosphere and the transition region, based on data from the first few months of OGO-III operation, will be described.

Vasyliunas, V. M., "Low Energy Electrons in the Magnetosphere and Transition Region as Observed by OGO-I and OGO-III," presented at the Summer Institute, Physics of the Magnetosphere, Boston College, June 19-28, 1967. To be published in *Physics of the Magnetosphere*.

Vasyliunas, V. M., "A Survey of Low Energy Electrons in the Evening Sector of the Magnetosphere with OGO-I and OGO-III," to be published in *J. Geophys. Res.*

ABSTRACT: Observations of electrons of energy 125 to ~ 2 kev with the OGO-I satellite and of electrons of energy 40 ev to ~ 2 kev with OGO-III (by means of modulated Faraday cup detectors) are used to investigate the low energy electron population in the magnetosphere within the local time range ~ 17 to ~ 22 hours. Intense fluxes of these electrons are confined to a spatial region, termed the plasma sheet, which is an extension of the magnetotail plasma sheet discovered by the Vela satellites and is identified with the soft electron band first detected by Gringauz. The plasma sheet extends over the entire local time range studied in this investigation, from the magnetospheric tail past the dusk meridian toward the dayside magnetosphere. In latitude it is confined to within 4-6 Re of the geomagnetic and/or solar magnetospheric equatorial plane, in agreement with observations already reported from the Vela satellites; no electron fluxes are detected high above the equator, not even very near the magnetopause. In radial distance the plasma sheet is terminated by the magnetopause on the outside and by a well-defined sharp inner boundary on the inside. The inner boundary has been traced from the equatorial region to the highest latitudes investigated, $\sim 40^\circ$; during geomagnetically quiet periods it is observed at an equatorial distance of 11 ± 1 Re and appears to extend to higher latitudes along magnetic field lines. Weak or no electron fluxes are found between the inner boundary of the plasma sheet and the outer boundary of the plasmasphere. Detection (by an indirect process) of the very high ion densities within the plasmasphere gives positions for its boundary in good agreement with other determinations. During periods of magnetic bay activity the plasma sheet extends closer to the earth; the inner boundary of the plasma sheet is then found at equatorial distances of 6-8 Re. This is most simply interpreted as the result of an actual inward motion of the plasma during a bay. In one case it was possible to associate the beginning of this motion with the onset of the bay and to estimate an average radial speed of ~ 12 km/sec, from which an electric field corresponding to ~ 48 kilovolts across the magnetospheric tail was inferred. Within the plasma sheet the electron population is characterized by densities from 0.3 to 30 cm^{-3} and mean energies from 50 to 1600 ev and higher, with a strong anticorrelation between density and mean energy so that the electron energy density ($\sim 1 \text{ kev cm}^{-3}$) and energy flux ($\sim 3 \text{ ergs cm}^{-2} \text{ sec}^{-1}$) show relatively little variation. The lower energies and higher densities tend to occur during periods of geomagnetic disturbance. The non-observation of electrons in regions above the plasma sheet implies an upper limit on the electron density of $5 \times 10^{-2} \text{ cm}^{-3}$ if their mean energy is assumed to be ~ 50 ev (typical of the magnetosheath) and 10^{-2} cm^{-3} if the energy is ~ 1 kev (typical of the plasma sheet). At the inner boundary of the plasma sheet there is a sharp softening of the electron spectrum with decreasing radial distance but apparently little change in the electron density. The electron energy density decreases across the inner boundary roughly as $\sim \exp(\text{distance}/0.4 \text{ Re})$ during quiet periods; during times of magnetic bay activity the energy density decreases as $\sim \exp(\text{distance}/0.6 \text{ Re})$ and there is a more complicated spatial structure of density and mean energy.

B-04 (Cline, Hones, Positron Search and Gamma-Ray Spectrum)

Cline, T. L., S. S. Holt, and E. W. Hones, Jr., "High-Energy Solar X-Rays of July 1966," *J. Geophys. Res.* 73, 434, Jan. 1968. GSFC X-611-67-348, Preprint.

ABSTRACT: The time history and differential intensity of solar X-rays of energies from 80 to more than 500 KeV were observed during the flare event of 7 July 1966. These measurements, made from a solar-oriented stable platform on OGO-III, cover the highest differential energy range studied thus far and indicate the greatest intensity in hard X-rays of any solar event observed to date. Three intensity peaks occurred at about 0027, 0029 and 0037 UT, coinciding with the times of microwave and optical intensity maxima. A study of the spectral and temporal characteristics of the X-ray emission, and comparison with the radio and optical data, indicate a non-thermal bremsstrahlung origin for the X-rays.

Cline, T. L., and E. W. Hones, Jr., "Search for Low-Energy Interplanetary Positrons," presented at 10th International Cosmic-Ray Conference, Calgary, Canada, June 1967. Accepted for publication in the *Canadian Journal of Physics*.

ABSTRACT: Preliminary results of an experiment designed to detect and measure the intensity of interplanetary positrons of energy 0 to 3 MeV with the satellites OGO-I and OGO-III are outlined. Evidence for a statistically significant counting rate of detected positrons is presented, and the possibility that these particles represent a true primary component rather than a background effect, such as cosmic-ray induced secondaries in the detector, is considered. It is shown that the apparent intensity of low-energy positrons, assuming that value derived from their counting rate, would be consistent with an equilibrium charge ratio. This result would not be predicted with mechanisms involving the ionization of matter or the acceleration of electrons, but would be consistent with a strongly energy-dependent galactic trapping parameter allowing meson-decay electrons to slow down in great abundance, or with the existence of an independent source.

Holt, S. S., and T. L. Cline, "On the Generation of Synchrotron and X-ray Emission from Electrons with Energy Below MC^2 in Solar Flares," GSFC X-611-67-525, Preprint. Submitted for publication.

ABSTRACT: An attempt is made to reconcile a single source of electrons with both the hard x-ray and microwave radio emission observed at the peak of the solar flare of 7 July 1966. The spectral and temporal characteristics of the x-ray emission are used to determine the total number of electrons involved in the emission, as well as the shape of the generating electron spectrum. This is the first instance in which a generating electron spectrum has been directly inferred from experimental data. The spectrum is found to be $dJ = A(\gamma - 1)^{-5} d\gamma$, which is steep enough such that the bulk of the microwave emission originates from electrons with energies below mc^2 . Both the observed x-radiation and synchrotron radiation can be explained in terms of the same electron source if they are generated high in the chromosphere, in the vicinity of the flare site, where the average field is of the order of 1000 gauss.

B-06 (McDonald, Cosmic-Ray Isotopic Abundance-Evans, Low Energy Proton Analyzer)

Teegarden, B., "A Study of Low Energy Galactic Cosmic Rays from 1961 to 1965," GSFC X-611-67-8.

ABSTRACT: The results from a series of balloon flights beginning in 1961 and ending in 1965 are presented. Measurements of the cosmic ray intensity were made using a dE/dx and E detector sensitive to energies from 15 to 80 MeV/nucleon. The early balloon flights provided design information and also aided in the development of data handling techniques for later satellite versions of the detector which have been on IMP's I, II, and III and OGO's I and III. Proton and helium intensities at 85 MeV/nucleon are presented for the five year period covered by the balloon flight series. The behavior of the proton to helium ratio as a function of time is discussed within the framework of Parker's model for the solar modulation of cosmic rays.

In 1965 a modified version of the dE/dx and E detector with an extended energy range was flown for the first time. A cosmic ray helium spectrum from 60 to 500 MeV/nucleon measured by this detector is presented. The change in proton and helium intensities in this energy region from 1963 to 1965 is examined and compared with the results predicted by the various special cases of Parker's model.

A totally empirical atmospheric secondary proton spectrum is derived, based on simultaneous balloon and satellite measurements. This spectrum is compared with the secondary spectrum obtained from a nuclear emulsion measurement and the differences are discussed. Using our empirical secondary spectrum, we obtain an upper limit for the re-entrant albedo at Sioux Falls which is significantly less than values reported by other observers.

A measurement of the intensities of secondary deuterium and tritium was made in 1965. Using these results, we obtain a value for the global average production of tritium in the earth's atmosphere. The implications of this result regarding the problem of tritium balance in the atmosphere are discussed.

B-08 (Van Allen, Low Energy Electron and Proton Detector)

Frank, L. A., "Several Observations of Low-Energy Protons and Electrons in the Earth's Magnetosphere with OGO-III," University of Iowa Report 66-48, November, 1966, also *J. Geophys. Res.*, 72, No. 7, April 1, 1967.

ABSTRACT: Simultaneous observations of proton ($190 \text{ eV} \leq E \leq 48 \text{ keV}$) and electron ($170 \text{ eV} \leq E \leq 46 \text{ keV}$) differential energy spectrums during segments of three outbound traversals of OGO-III through the magnetosphere for the period 11-15 June 1966 on L-shells 3.3 to 16 are presented. Proton intensities at $L = 4$ on 15 June 1966 were $8 \times 10^5 \text{ (cm}^2\text{-sec-sr)}^{-1}$ ($330 \leq E \leq 530 \text{ eV}$), $\lesssim 1.5 \times 10^6 \text{ (cm}^2\text{-sec-sr)}^{-1}$ ($4.7 \leq E \leq 7.6 \text{ keV}$) and $\lesssim 10^6 \text{ (cm}^2\text{-sec-sr)}^{-1}$ ($16 \leq E \leq 26 \text{ keV}$) and at $L = 7.5$ were $\leq 5 \times 10^4 \text{ (cm}^2\text{-sec-sr)}^{-1}$ ($330 \leq E \leq 530 \text{ eV}$), $4 \times 10^6 \text{ (cm}^2\text{-sec-sr)}^{-1}$ ($4.7 \leq E \leq 7.6 \text{ keV}$) and $6 \times 10^6 \text{ (cm}^2\text{-sec-sr)}^{-1}$ ($16 \leq E \leq 26 \text{ keV}$) with local pitch angles $78^\circ (\pm 4^\circ)$ and at a geomagnetic latitude $23^\circ (\pm 1^\circ)$. Peak intensities of protons ($30 \leq E \leq 48 \text{ keV}$) were observed at $L \approx 7.0$. A preliminary order-of-magnitude estimate of the total energy of trapped protons ($190 \text{ eV} \leq E \leq 48 \text{ keV}$) within the earth's magnetosphere is 5×10^{21} ergs and the estimated contribution from this low-energy proton distribution to the quiet-time terrestrial ring current field at the earth's surface is $\sim 10\gamma$. A transient, narrow peak of relatively high low-energy proton and electron intensities within the energy range $\sim 300 \text{ eV}$ to 2 keV at $L \approx 4$ with width $\Delta L \sim 1$ is also observed. Typical characteristics of proton and electron intensity 'spikes' at peak intensities in the late evening sector of the earth's magnetic tail are (a) approximately equal proton ($190 \text{ eV} \leq E \leq 48 \text{ keV}$) and electron ($170 \text{ eV} \leq E \leq 46 \text{ keV}$) energy densities, $\sim 10^{-9} \text{ erg (cm)}^{-3}$ each, (b) approximately equal proton and electron densities over the above energy range, $\sim 1 \text{ (cm)}^{-3}$ each, and (c) largely dissimilar differential energy spectrums, proton spectrums with intensity peaks noncoincident in energy with those of the electron intensity peaks and significantly broader (harder) in the high-energy tail ($E \geq 3 \text{ keV}$) than the relatively steep (soft) electron spectrums in this energy range.

Frank, L. A., "Initial Observations of Low-Energy Electrons in the Earth's Magnetosphere with OGO-III," University of Iowa Report 66-39, August 1966, also *J. Geophys. Res.*, 72, No. 1, Jan. 1, 1967.

ABSTRACT: Initial observations of electrons over the energy range extending from $\sim 100 \text{ eV}$ to 50 keV at geocentric radial distances $8\text{--}20 R_E$ in the dark hemisphere of the earth's magnetosphere with electrostatic analyzers borne on OGO-III are presented for the inbound pass of the satellite on June 12-13, 1966. The electron differential energy spectrums typically are characterized by a single peak in intensities occurring in the energy range $\sim 0.8\text{--}10 \text{ keV}$ and at lower energies with increasing geocentric radial distance, by broader widths with decreasing radial distance, and by greater slopes for electron energies $E_e \gtrsim 5 \text{ keV}$ with increasing radial distance. The radial profiles of unidirectional and omnidirectional, integral and differential intensities, and energy densities of electrons within the above energy range are characterized by catastrophic variations in magnitude that are presumably reflections of both temporal and spatial variations in intensities. A relatively uncommon example of an electron spectrum with two peaks in intensities at $E_e \approx 1 \text{ keV}$ and $\approx 10 \text{ keV}$ is examined during the onset of the event and the peaks in electron intensities were found to occur at lower energies with increasing time. Beyond $\sim 13 R_E$ many electron spectrums are 'monoenergetic' to the extent that $\gtrsim 75\%$ of the energy flux is shared among electrons in the energy range $1\text{--}3 \text{ keV}$, as an example, although measurable electron intensities are observed over the entire energy range $\sim 400 \text{ eV}$ to 50 keV . In contrast with the persistent softening of the electron spectrums with increasing radial distance between 8 and $20 R_E$, the electron energy densities in the peaks of intensities do not show a marked radial dependence beyond $\sim 13 R_E$. The observed electron ($E_e > 280 \text{ eV}$) energy densities in the peaks of the radial profiles almost always rise to $\sim 10^{-9} \text{ erg/cm}^3$, an effect which may be indicative of an instability or 'saturation' of the local magnetic field, and are significant in substantially distorting the geomagnetic field beyond $\sim 8 R_E$. Typical values of the ratios of intensities $J(E_e > 610 \text{ eV})/J(E_e > 45 \text{ keV})$ are 10^4 in the magnetospheric tail. The maximum temporal resolution of the apparatus is $\sim 100 \text{ msec}$: temporal variations of low-energy electron intensities by factors $\gtrsim 2$ occurred usually in periods \sim seconds to several minutes.

Frank, L. A., "On the Temporal Variations of Low-Energy Proton Intensities in the Outer Radiation Zone during Geomagnetic Storms," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 155, March 1967.

ABSTRACT: Observations of proton intensities over the energy range extending from 200 eV to 50 keV with an array of electrostatic analyzers borne on OGO-III reveal large increases of proton ($3 \text{ keV} \lesssim E \lesssim 50 \text{ keV}$) intensities near the geomagnetic equator from $L \approx 3.0$ to 6.5 on June 25, 1966, and July 9, 1966, during two small geomagnetic storms. At $L = 3.5$ on July 9 the intensities of protons ($31 \text{ keV} \leq E \leq 49 \text{ keV}$) increased by factors $\gtrsim 30$ over the prestorm intensities. On June 25 and July 9 the peak proton ($200 \text{ eV} \leq E \leq 50 \text{ keV}$) energy densities at the geomagnetic equator were $2 \times 10^{-7} \text{ erg (cm)}^{-3}$ at $L = 4.5$ and $4.5 \times 10^{-7} \text{ erg (cm)}^{-3}$ at $L = 3.3$, respectively. This energy density is predominantly shared by protons in the energy range extending from $\sim 3 \text{ keV}$ to 50 keV. The apparent mean lifetimes of these low-energy protons are similar to the recovery times for these two magnetic storms, and the total energy of these outer-zone protons is sufficient to account for the main phase Dst (H). The proton differential energy spectrums, angular distributions, and the decay of the proton intensities as functions of L during the July 9 geomagnetic storm (main phase Dst (H) $\approx -50\gamma$) are presented.

Frank, L. A., "The Particle Population of the Magnetosphere," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 146, March 1967.

Frank, L. A., "On the Extraterrestrial Ring Current During Geomagnetic Storms," University of Iowa Report 67-9, February 1967, *J. Geophys. Res.*, 72, No. 15, 3753-3767, August 1, 1967.

ABSTRACT: Measurements of the differential energy spectrums of protons and electrons, separately, over the energy range extending from $\sim 200 \text{ eV}$ to 50 keV with a sensitive array of electrostatic analyzers borne on the earth-satellite OGO-III reveal large temporal variations in intensities of these low-energy charged particles at low and moderate latitudes in the outer radiation zone during two moderate geomagnetic storms in late June and early July 1966. At $L = 3.5$ on July 9, for example, the intensities of protons ($31 \text{ keV} \leq E \leq 49 \text{ keV}$) increased by factors $\gtrsim 30$ over the pre-storm intensities. The peak proton ($200 \text{ eV} \leq E \leq 50 \text{ keV}$) energy densities at the magnetic equator for June 23 (relative magnetic quiescence), June 25 (Dst (H) $\approx -30\gamma$), and July 9 (Dst (H) $\approx -50\gamma$) were $9 \times 10^{-8} \text{ erg (cm)}^{-3}$ at $L = 6.8$, $2 \times 10^{-7} \text{ erg (cm)}^{-3}$ at $L = 4.5$, and $5 \times 10^{-7} \text{ erg (cm)}^{-3}$ at $L = 3.3$ respectively. This energy density is predominantly shared by protons in the energy range ~ 3 -50 keV. The total energy of these low-energy protons and electrons within the earth's magnetosphere is sufficient to account for the depression of the geomagnetic field (Dst (H)) observed at the earth's surface over low and moderate latitudes; hence these charged particles may be identified as the major contributors to the storm-time extraterrestrial ring current. Electrons ($200 \text{ eV} \leq E \leq 50 \text{ keV}$) are found to provide approximately 25% of this storm-time ring current. The apparent mean lifetimes of low-energy protons in the outer radiation zone are in agreement with calculated lifetimes assuming charge-exchange collisions with the ambient neutral and charged constituents of the terrestrial exosphere as the predominant loss mechanism.

Frank, L. A., and R. L. Swisher, "On the Energy Fluxes of Low-Energy Protons and Positive Ions in the Earth's Inner Radiation Zone," University of Iowa Report 67-33, June, 1967, Letters, *J. Geophys. Res.*, 73, No. 1, Jan. 1968.

ABSTRACT: A search for the large energy fluxes of low-energy protons or positive ions ($500 \text{ eV} \lesssim E \lesssim 1 \text{ MeV}$) in the earth's inner radiation zone as previously reported by Freeman via the analysis of the responses of CdS crystals borne on the earth-satellite Injun 1 is reported here utilizing recent measurements of energy fluxes of protons and positive ions within the energy range 100 eV to 4.2 MeV with earth-satellites OGO-III and Injun 4. These recent measurements provide upper limits for these proton and positive-ion energy fluxes which are less by factors ~ 10 to 100 when compared to the Injun 1 observations during 1961. The upper limits reported here strongly indicate that large energy fluxes of low-energy protons or positive ions, $\sim 50 \text{ ergs (cm}^2\text{-sec-sr)}^{-1}$, are not a feature of the inner radiation zone.

Frank, L. A., "Recent Observations of Low-Energy Charged Particles in the Earth's Magnetosphere," presented at the *Summer Institute on Physics of the Magnetosphere*, Boston College, June 1967, University of Iowa Report 67-36, July 1967.

ABSTRACT: Several recent observations of low-energy proton and electron intensities within the energy range ~ 100 eV to 50 keV in the earth's radiation zones with a sensitive array of electrostatic analyzers borne on the earth-satellite OGO-III during mid-1966 are summarized. Measurements of charged particles of the extraterrestrial ring current during a moderate geomagnetic storm, of the low-energy proton and electron distributions in the vicinity of the midnight 'trapping boundary' near the magnetic equatorial plane, and of upper limits for proton and ion ($100 \text{ eV} \leq E/Q \leq 50 \text{ keV}$) energy fluxes deep within the inner radiation zone are presented together with several introductory comments concerning the morphology of the omnidirectional intensities of energetic electrons ($E \geq 40 \text{ keV}$, $\geq 230 \text{ keV}$ and $\geq 1.6 \text{ MeV}$) at the magnetic equator in the outer radiation zone.

Frank, L. A., "On the Distributions of Low-Energy Protons and Electrons in the Earth's Magnetosphere," presented at the *Advanced Study Institute, Earth's Particles and Fields*, Stadt Freising, Germany, 31 July-11 August, 1967, University of Iowa Report 67-54, September 1967.

ABSTRACT: Recent observations of low-energy proton and electron intensities over the energy range ~ 100 eV to 50,000 eV in the local evening-midnight quadrant of the magnetosphere near the geomagnetic equatorial plane at 5 to 15 R_E (R_E , earth radii) geocentric radial distances are summarized with several comments concerning the relationship of these distributions of low-energy charged particles with earlier measurements. Of particular interest are the morphology of the distributions of low-energy protons of the extraterrestrial ring current during magnetic storms, the temporal variations of low-energy electron spectrums in the outer radiation zone and several salient features of the distributions of low-energy electrons in the vicinity of the 'trapping boundary' in the dark hemisphere of the earth's magnetosphere at $\sim 8 R_E$ geocentric distance near the magnetic equator.

Frank, L. A., and W. L. Shope, "A Cinematographic Display of Observations of Low-Energy Proton and Electron Spectra in the Terrestrial Magnetosphere," University of Iowa Report 67-67, November 1967.

ABSTRACT: A massive series of observations of the differential energy spectra of proton and electron intensities over the energy range ~ 300 eV to 50 keV within the earth's magnetosphere and its environs has been obtained with an array of electrostatic analyzers borne on the earth-satellite OGO-III. In order to supplement the presently existing publications derived from these observations and to provide further insight into the distributions of low-energy charged particles within the earth's radiation zones over geocentric radial distances ~ 2 to 20 R_E (R_E , earth radii) we have utilized a SC 4020 microfilm plotter to construct a cinematographic display of the differential energy spectra of proton and electron intensities which spans a complete circuit of the spacecraft around the earth, or ~ 50 hours of substantially continuous observations beginning at 1330 U. T. on July 14, 1966. This cinematographic display comprises approximately 18,000 individual frames and summarizes some 550,000 intensity measurements. A description of the methods and graphic results is furnished as an aid in interpretation of this visual presentation of the observations.

Swisher, R. L., and L. A. Frank, "Charge-Exchange Lifetimes for Low-Energy Protons in the Outer Radiation Zone," to be presented at the 49th AGU Annual Meeting, Washington, D. C., April 8-11, 1968.

ABSTRACT: The directional differential intensities of protons over the energy range ~ 200 eV to 49 keV injected into the outer radiation zone (i. e., the extraterrestrial ring current) during the main phase of the geomagnetic storm during early July 1966 were monitored with a sensitive array of electrostatic analyzers borne on the earth-satellite OGO-III. Proton intensities are greatly increased throughout the outer radiation zone for L-values $\gtrsim 3$ during the main phase of the moderate geomagnetic storm, and the injection mechanism effectively ceases to be effective after the storm main phase. These proton intensities are shown to exponentially decay with lifetimes ranging from 15 to 105 hours in agreement with calculated lifetimes invoking measured charge-exchange cross-sections for protons incident upon atomic hydrogen and a model of the atomic hydrogen density in the earth's exosphere. The atomic hydrogen density model for the terrestrial exosphere providing the best fit to the observed proton lifetimes over geocentric radial distances 2.4 to 4.8 earth radii (corresponding to densities ~ 30 to 260 hydrogen atoms $(\text{cm})^{-3}$) considers only atoms in ballistic orbits above the exosphere as opposed to a model atmosphere which includes an additional atomic hydrogen population in elliptical orbits about the earth.

B-09 (Winckler and Arnoldy, Trapped Radiation, Electron Spectrometer)

Arnoldy, R. L., S. R. Kane, and J. R. Winckler, "Energetic X-Ray Bursts from Solar Flares," presented at the American Astronomical Society Meeting on Solar Astronomy, October 3-5, 1966, Boulder, Colorado.

ABSTRACT: By means of the sensitive ionization chamber on the OGO-I and OGO-III spacecraft, more than 15 solar flare x-ray bursts in the energy range 20-50 Kev have been recorded. The present study consists of a quantitative comparison between solar radio and optical emissions coincident with the x-ray flux from these events and from about 12 events previously recorded with balloons and rockets. Detailed subjects include the rise and decay characteristics of the bursts, the proportionality between the x-ray amplitude and the radio flux in the centrimetric region, the association with Type 2, 3 and 4 radio bursts and energetic particles observed from the same flare, and the physical location and characteristics of the time-coincident H α emissive regions. In some cases the detailed time structure of the x-ray bursts may be studied by a power spectrum analysis. Preliminary results indicate:

1. A close time correlation between the centrimetric radio emission and the x-rays as found previously.
2. A rough proportionality between the intensity of the x-rays and the intensity of 10 centimeter emission.
3. At least half of the 10 cm bursts of peak flux greater than $6 \times 10^{-22} \text{ w/m}^2 \cdot \text{cycle} \cdot \text{sec}$ during recording times of the satellite are accompanied by observable energetic x-ray increases. All 10 cm radio bursts above $20 \times 10^{-22} \text{ w/m}^2 \cdot \text{cycle} \cdot \text{sec}$ show detectable x-rays.
4. At least one case of energetic particle production by a flare without energetic x-rays or microwave emission.
5. Electrons of roughly the energy required for producing the x-rays by bremsstrahlung were observed directly in space following several of the bursts.

Arnoldy, R. L., S. R. Kane, and J. R. Winckler, "Energetic Solar Flare X-Rays Observed by Satellite and Their Correlation with Solar Radio and Energetic Particle Emission," Univeristy of Minnesota Technical Report CR-97, June 1967.

ABSTRACT: Ionization chambers aboard the OGO-A and OGO-B spacecrafts with a response window for x-rays between 10 kev and 50 kev have accumulated more than 6,000 hours of operation in space outside the earth's magnetosphere. Approximately thirty solar flare x-ray bursts have been detected between 5 September 1964 and 20 June 1966. These energetic x-ray bursts have been correlated with 3 and 10 cm solar radio emission and solar flare electron and proton events measured in space.

A proportionality is observed between the time integrated x-ray and radio fluxes and for a given flare the rise time, decay time and total duration of the radio and x-ray bursts are similar. Exponential time constants between 1 and 10 minutes characterize the decay. All 3 or 10 cm radio bursts greater than 80 flux units are accompanied by an x-ray event greater than $3 \times 10^{-7} \text{ ergs cm}^{-2} \text{ sec}^{-1}$ and the probability of detecting an x-ray event is negligible unless the radio spectrum includes the centrimetric range of wavelengths. All but three of the x-ray events were correlated with SWF ionospheric disturbances. A number of large flare events occurred in which all of the energetic processes were observed; namely, solar protons, solar electrons, energetic bremsstrahlung and high frequency radio emission. In comparing energetic x-rays with solar particle emission the best correlation seems to exist with the solar electron events observed in space. Many solar proton events occurred without a detectable burst of energetic x-rays.

It is shown that the results are consistent with a source in the flare region consisting of an active volume in a magnetic field containing hot or energetic electrons which lose energy predominantly by collisions with a much cooler gas and produce x-rays by bremsstrahlung.

Arnoldy, R. L., S. R. Kane, and J. R. Winckler, "A Study of Energetic Solar Flare X-rays," *Solar Physics*, 2, 171-178, 1967.

ABSTRACT: A new series of solar flare energetic X-ray events has been detected by an ionization chamber on the OGO-I and OGO-III satellites in free space. These X-rays lie in the range 10-50 keV, and a study has been made of their relationship to 3 and 10 cm radio bursts and with the emission of electrons and protons observed in space. The onset times, times of maximum intensity and total duration are very similar for the radio and X-ray emission. Also, the average decay is similar and usually follows an exponential type behavior. However, this good correlation applies most often to the 'flash' phase of flares, whereas subsequent surges of activity from the same eruption may produce microwave emission or further X-ray bursts not closely correlated. An approximate proportionality is found between the total energy content of the X-rays and of the 3 and 10 cm integrated radio fluxes. These measurements suggest that the X-ray and microwave emission have a common energizing process which determines the time profile of both. The recording of electrons greater than 40 keV by the Interplanetary Monitoring Probe (IMP satellite) has been found to correlate very well with flares producing X-ray and microwave emission provided the propagation path to the sun is favorable. There is evidence that the acceleration of solar protons may not be closely associated with the processes responsible for the production of microwaves, X-rays, and interplanetary electrons.

The OGO ionization chamber responds to energies (10-50 keV) intermediate between the soft X-rays giving SID disturbances (1-10 keV) and energetic quanta previously measured with balloons (50-500 keV). Proposed source mechanisms should be capable of covering this range of energies including the most energetic quanta occasionally observed.

Arnoldy, R. L., S. R. Kane, and J. R. Winckler, "The Observation of 10-50 Kev Solar Flare X-rays by the OGO Satellites and Their Correlation with Solar Radio and Energetic Particle Emission," paper presented at IAU Symposium No. 35, Budapest, Hungary, September 4-8, 1967, U. of Minn. Technical Report CR-107.

ABSTRACT: More than 70 cases have been observed of energetic solar flare x-ray bursts by large ionization chambers on the OGO satellites in space. The ionization chambers have an energy range between 10 and 50 Kev for x-rays and are also sensitive to solar protons and electrons. A study has been made of the x-ray microwave relationship and it is found that the total energy released in the form of x-rays between 10 and 50 Kev is approximately proportional to the peak or total energy simultaneously released in the form of microwave emission. For a given burst the rise time, decay time and total duration are similar for the 10-50 Kev x-rays and the 3 or 10 cm radio emission. Roughly exponential decay phases are observed for both emissions with time constants between 1 and 10 minutes. All 3 or 10 cm radio bursts with peak intensity greater than 80 solar flux units are accompanied by an x-ray burst greater than 3×10^{-7} ergs $\text{cm}^{-2} \text{sec}^{-1}$ peak intensity. The probability of detecting such x-ray events is low unless the radio spectrum extends into the centimetric range of wavelengths. The best correlation between $\text{cm-}\lambda$ and energetic x-rays is observed for the first event in a flare. Subsequent structure and second bursts may not correspond even when the radio emission is rich in the microwave component. A very good correlation exists between the occurrence of large SID events (importance-3) and energetic x-rays. The overall correlation for importance 1, 2 and 3 is 55%. Almost 90% of the x-ray bursts were accompanied by known SID events. The mechanism for the energetic x-rays is shown to be bremsstrahlung probably of fast electrons on a cooler plasma. The mechanism for the radio emission is basically uncertain. However, if it is assumed to be synchrotron radiation then a relationship is developed between density and magnetic field which meets the observed quantitative results. One finds, on the average, that 5×10^{-54} joules $\text{m}^{-2} (\text{CPS})^{-1}$ of microwave energy at earth are required per electron at the sun to provide the radio emission for the various events.

A strong correlation between interplanetary solar flare electrons observed by satellite and x-ray bursts are shown to exist. This correlation is weak for solar proton events. One may infer a strong propagation asymmetry for solar flare electrons along the spiral interplanetary magnetic field.

Arnoldy, R. L., S. R. Kane, and J. R. Winckler, "An Atlas of 10-50 Kev Solar Flare X-rays Observed by the OGO Satellites 5 September 1964 to 31 December 1966," U. of Minn. Technical Report CR-108, January, 1968.

Kane, S. R., "Application of an Integrating Type Ionization Chamber to Measurements of Radiation in Space," Ph.D. thesis, December, 1967, also U. of Minn. Technical Report CR-106.

ABSTRACT: An integrating type ion chamber experiment, using a resetting drift-type electrometer and designed to fly on the OGO-I and III satellites is described. The chamber is demonstrated to have an accuracy and stability of $\sim 1\%$ during its operation in space over a period of nearly three years.

The minimum energy for penetration by protons and electrons is 12 and 0.6 MeV respectively. The response to 40 KeV electrons (through bremsstrahlung) is about 10^{-7} x (response at energies > 600 KeV). The response to x-rays in 10-150 KeV range is peaked at ~ 20 KeV; below 10 KeV the response is $\approx 10^{-2}$ x (response at 20 KeV). For 1 particle $\text{cm}^{-2} \text{sec}^{-1}$ of 20 KeV photons, electrons with energy $\gtrsim 1$ MeV, and minimum ionizing nuclei with charge Ze the pulsing rate of the chamber is respectively 0.2, 7.0, and $5.5 Z^2$ NPPS (Normalized Pulses Per Second) $\times 10^3$.

The OGO-I and III ion chamber measurements reported here cover the period 10 September, 1964-2 July, 1966, a period following the minimum in solar activity. The cosmic ray maximum, as determined from these measurements, occurred during 11-15 May, 1965 when the ion chamber rate in free space was $65.5 \text{ NPPS} \times 10^3$. For this time the total chamber rate computed from the "known" cosmic ray spectrum is $74 \text{ NPPS} \times 10^3$, the contributions from protons, He-nuclei, S-nuclei, electrons and nuclear interactions being about 31, 18, 33, 5 and 13 percent respectively. The difference of 12% between the total computed and observed rates could be due to a number of known factors.

The relationship between the free space ion chamber and Deep River neutron monitor during March 1960-May 1965 is found to be linear: fractional change in free space chamber $\approx k$ x (fractional change in Deep River monitor), where $K \approx 4.5$. After May, 1965 K is < 4.5 which implies a hysteresis effect.

The differential response curve of the OGO chamber for the primary cosmic rays is peaked at about 1 and 2 BV at solar minimum and solar maximum respectively. Most of the response of an ion chamber is found to be concentrated in a rather narrow rigidity interval of the primary spectrum, the precise interval depending on the location of the chamber:

Free Space	1.5 - 2.5 BV
High latitude (10 mb)	2.5 - 3.5 BV
Minneapolis (10 mb)	3.0 - 4.0 BV

These results give the rigidity dependence of the modulation consistent with $p^{-0.9}$. (Period 1960-1965, $1.5 \leq R \leq 4.0 \text{ B}$.)

At high latitudes variation of the chamber rate with altitude was computed taking into account the earth's shadow effect and the observed chamber rate in free space. At balloon altitudes the computed rate is found to be lower than the observed rate; the difference is maximum ($\sim 100\%$) at solar maximum and is presumably due to the secondaries produced in the atmosphere.

Fluctuations of $\sim 5\%$ magnitude, observed in the free space chamber rate averaged over about 90 seconds, can be explained in terms of the statistical fluctuations in (a) number of primaries passing through the chamber, (b) number of nuclear interactions in the chamber, (c) energy deposited in individual interactions and (d) heavy nuclei stopping inside the chamber gas. No single process was found to be the dominating factor.

Kane, S. R., and D. J. Hofmann, "Difference in Total Ionization Rate of Solar Particles Inside and Outside the Magnetosphere," to be presented at the April 1968 AGU Meeting, Washington, D. C.

ABSTRACT: Identical ionization chambers aboard the satellites OGO-I and OGO-III are utilized in a comparison of the total ionization rate due to solar particles in front of the magnetosphere and in the magnetospheric tail at 15-20 earth radii.

The ionization chambers consist of a seven-inch diameter spherical aluminum shell with a wall thickness of 0.81 mm (proton cutoff—12 MeV). The two units have been compared in flight by simultaneously measuring the galactic cosmic ray background. The ionization rates are in agreement to within 1% using the pre-flight laboratory calibrations. Although no information can be obtained as to the type of particle or its energy spectrum, the high degree of accuracy in intercomparison and the high degree of sensitivity ($0.01 \text{ protons/cm}^2\text{-sec}$ at 20 MeV) make the ionization chamber a useful tool for studying the spatial characteristics of the radiation.

During the period from August 28, 1966 to September 30, 1966, a series of six distinct solar particle events were observed aboard OGO-III. Data from the OGO-I chamber were obtained during short periods when the satellite was operating. Data from the times of simultaneity are presented and the following results are established:

(a) During the early phases of an event, the ion chamber outside the magnetosphere indicates a higher ionization rate than inside the magnetosphere.

(b) During the decay phase the two sets of data are in average agreement; however, data from outside the magnetosphere tends to have more structure than that inside the magnetosphere.

(c) From the observed roll modulation the degree of anisotropy is found to be considerable outside the magnetosphere. Data from inside the magnetosphere are presently being analyzed for anisotropies.

Pfitzer, K. A., and J. R. Winckler, "The Decay and Injection of Artificial and Natural Electrons in the Inner Zone," to be presented at the April 1968 AGU Meeting, Washington, D. C.

ABSTRACT: A five channel magnetic electron spectrometer measuring electrons from 50 Kev to 4 Mev flown on the OGO-I and OGO-III satellites studied the long term time and space variations of the inner zone from September 1964 to December 1966, a period of low solar activity. Before September 2, 1966 electrons having energies greater than 290 Kev at L's less than 1.8 are observed to follow the decay curves of the Starfish electrons. 290-690 Kev electrons have decay times of 350, 450 and 450 days for L's of 1.3, 1.5 and 1.7 respectively. The decay rates are energy as well as L dependent, the higher energy electrons decaying more rapidly than the lower energy electrons.

The September 2, 1966 solar flare, one of the first large disturbances of the new solar cycle, was observed to inject electrons of energy less than 690 Kev to L's as low as 1.3; whereas, no increase in the flux was observed for electrons of energy greater than 690 Kev for L's less than 2.0. The number of electrons added to the inner zone between 50-690 Kev by the above event is independent of L, the percentage increase, however, varies from 40% at L = 1.3 to two orders of magnitude at L = 2.4. The large increase for L = 2.0 decays rapidly such that by mid October 1966 post-storm fluxes differ from the pre-storm fluxes by less than 50%. This "new" inner zone then resumes its "Slow" decay as observed during the two years prior to the September 2, 1966 event. All electrons above 690 Kev below L = 1.8 can still be referred to as Starfish electrons, whereas those having energy less than 690 Kev are now primarily of natural origin throughout the entire inner zone.

B-10 (Smith, Holzer, Triaxial Search Coil Magnetometer)

McLeod, M. G., C. T. Russell, R. E. Holzer, and E. J. Smith, "Magnetic Fluctuations in the Vicinity of the Earth's Bow Shock Observed on OGO-I and OGO-III," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 169, March 1967.

ABSTRACT: Search coil magnetometers on OGO-I and OGO-III have measured the magnetic fluctuations at frequencies less than 1000 hz at a number of bow shock crossings. Within the shock transition and in the magnetosheath immediately behind the shock, frequencies up to several hundred hz are observed. Bursts of energy at frequencies of 100 hz or more are found in relatively sharply bounded regions behind the shock. Precursor waves at frequencies from one to several hz extend from the shock into the interplanetary medium. Multiple crossings of the shock are observed on most orbits, indicating that the shock is constantly in motion.

McLeod, M. G., R. E. Holzer, and E. J. Smith, "Spectra, Direction of Propagation, and Polarization of Waves in the Magnetosheath in the Frequency Range from .01 to 140 Hz," submitted for presentation at the 1968 Spring AGU Meeting, Washington, D. C.

ABSTRACT: Magnetic fluctuations in the magnetosheath with frequency components above .01 hz have been measured by triaxial search coil magnetometers on OGO-I and OGO-III. The three components of the ambient field variations were digitally sampled at three telemetry rates corresponding to upper Nyquist frequencies of 140, 17.4, and 2.2 hz. Fluctuations in the frequency range from 14 to 140 hz often take the form of fairly monochromatic signals lasting a few tenths of a second, sometimes reaching amplitudes of 1 gamma. Fluctuations at lower frequencies do not seem to have

this monochromatic character. Propagation direction, relative to the magnetic field and the magnetosheath boundaries, and signal polarization as determined by power spectra and cross spectra, will be discussed.

Olson, J. V., M. G. McLeod, R. E. Holzer, and E. J. Smith, "High Frequency Magnetic Fluctuations Associated with the Earth's Bow Shock," submitted for presentation at the 1968 Spring AGU Meeting, Washington, D. C.

ABSTRACT: Magnetic noise associated with the earth's bow shock, in the frequency range 0.5 hz to 300 hz, has been detected with triaxial search coil magnetometers on OGO-I and OGO-III. Noise power spectra obtained throughout the shock front show a continuous spectrum of noise up to at least 10 hz. The character of the spectrum depends upon the location of the data sample within the shock. In addition to the continuous spectrum, bursts of noise in the frequency range 10 hz to 300 hz are also detected at the front. Several shock crossings were monitored at high data rates and provide alias-free waveform information up to about 100 hz. These records show the bursts of high frequencies to have amplitudes in the range 0.01γ to 0.1γ and to be circularly polarized.

Russell, C. T., R. E. Holzer, and E. J. Smith, "Preliminary Results from the OGO-III Search Coil Magnetometer within the Magnetosphere in the Frequency Range from 10 to 1000 hz," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 168-169, March 1967.

ABSTRACT: The satellite OGO-III was launched on June 7, 1966, into a highly elliptical orbit with an apogee of 20.2 Earth radii. The satellite carried a triaxial search coil magnetometer whose outputs included five channels on each axis that gave a measure of the power present in five bands from 10 to 1000 hz. Preliminary results show broadband signals with center frequencies, usually in the range of 100 to 300 hz, and an amplitude, corresponding to the power integrated over the frequency band, of up to 0.5 gamma. These signals are quite variable in amplitude, however, and on occasion fall below the threshold of detection of the instrument. The location of their occurrence is also variable. The L shell of peak intensity on a particular orbit may be anywhere from 2 to 6 Earth radii. These results are consistent with those previously reported for the OGO-I satellite.

Russell, C. T., R. E. Holzer, and E. J. Smith, "Magnetic Fluctuations Between 30 and 1000 Hz within the Magnetosphere," submitted for presentation at the 1968 Spring AGU Meeting, Washington, D. C.

ABSTRACT: The OGO-III triaxial search coil magnetometer data have been used to study magnetic fluctuations in the magnetosphere in the frequency range of 30 to 1000 hz. During its first 23 orbits, approximately 46 days, the satellite was inertially stabilized permitting estimates of direction of wave propagation, in addition to estimates of power spectra and spatial distribution. During this interval most of the signals were observed inside the magnetic shell $L = 6$. The amplitude modulation of the waves ranged from 0 to 100% at quasi-periods of from about 30 to 200 seconds. The direction of propagation was characteristically neither wholly along or across the magnetic field.

After the 23rd orbit the satellite was spin stabilized with a rotational period of 100 seconds. The spin complicated the analysis of modulation and propagation but did not seriously affect spectral analysis or analysis of spatial distribution. Broad band signals, strongest in the range from 100 to 300 hz, with amplitudes of about 50 milligammas are common on the day side of the earth. Monochromatic noise is also commonly observed.

On the night side of the earth strong signals are rare. However when they do occur they have a very different character from those on the day side.

Russell, C. T., J. V. Olson, R. E. Holzer, and E. J. Smith, "OGO-III Search Coil Magnetometer Data Correlated with the Reported Crossing of the Magnetopause at $6.6V_E$ by ATS-1," submitted to *J. Geophys. Res.*

Smith, E. J., R. E. Holzer, M. G. McLeod, and C. T. Russell, "Magnetic Noise below 1000 hz Observed in the Magnetosheath by OGO-I and OGO-III," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 183, March 1967.

ABSTRACT: Search coil magnetometers on OGO-I and OGO-III, launched in September 1964 and June 1966, respectively, into eccentric orbits with apogees beyond $20 R_E$, have detected rapid magnetic variations in the magnetosheath, with frequency components extending up to 1000 Hz. These measurements are of interest because they may help clarify the dynamic physical processes occurring in the magnetosheath, as well as at the shock front and magnetopause, and may contribute to understanding extremely low-frequency wave propagation in plasmas. Although strongest at the magnetopause and bow shock, the magnetic noise is a persistent feature of the magnetosheath. The signals are non-stationary and show great variability in amplitude and frequency content. Power spectral density estimates have been made when they appear warranted by relatively stationary conditions. The long active lifetimes of both satellites and their repeated passage through the magnetosheath make it possible to study the relation between the noise properties, pertinent spatial parameters, and changing magnetic activity. The results of these investigations and a discussion of the most significant aspects of these signals will be presented.

Smith, E. J., R. E. Holzer, and M. G. McLeod, "Magnetic Measurements in the Magnetosheath at Frequencies up to 1000 Hz," submitted for presentation at the 1968 Spring AGU Meeting, Washington, D. C.

ABSTRACT: Triaxial search coil magnetometers on OGO-I and III have made copious measurements of rapid magnetic field changes in the magnetosheath at geocentric distances in excess of 20 earth radii. Naturally-occurring signals have been studied with an on-board spectrum analyzer which consists of five tuned filters logarithmically spaced between 3 and 1000 Hz. The magnetosheath has been found to contain magnetic noise at all times with strong components up to several hundred Hz.

Although reasonably well confined to the magnetosheath, noise bursts are observed sporadically just outside the bow shock. The observations are attributed to plasma waves, generated within the magnetosheath or at its boundaries, propagating in the fast, transverse electromagnetic mode at frequencies below the electron gyroresonance. The continuing analysis of these signals will be reported with emphasis on recent OGO-III results.

B-15 (Taylor, Atmospheric Mass Spectrum)

Taylor, H. A., M. W. Pharo, and H. C. Brinton, "Hydrogen and Helium Ions in the Magnetosphere: First Results from the OGO-III Satellite," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 62, March 1967.

ABSTRACT: Since the launch on June 11, 1966, direct measurements of the positive ions of hydrogen and helium have been obtained from the RF mass spectrometer experiment aboard the OGO-III satellite. Analysis of first results obtained during June and July 1966 shows that typical distributions of H^+ extend from a peak concentration of approximately 10^4 ions/cc at 1000 kilometers and 0700 hours local time to a minimum of 10 ions/cc or less at altitudes as great as 45,000 kilometers. Helium ions reach a maximum concentration of 10^3 ions/cc near 700 kilometers. At higher altitudes the distributions of He^+ closely parallel those of H^+ , with a typical H^+ to He^+ ratio of 100 to 1. The high altitude distributions of H^+ further define the existence of a beltlike region of ions, which was previously observed on the OGO-I satellite. The outer boundary of this belt, which is often characterized by sharp decreases in H^+ concentrations to values of 10 ions/cc or less, is observed to extend over a wide range of L values, from $L = 3.3$ to $L = 8$. In the local time sector of 2200 to 0200 hours, an inverse correlation is observed between the boundary L coordinate and the magnetic activity index K_p , which suggests some relationship between magnetic disturbances and large-scale expansion and contraction of the outer ionosphere.

Taylor, H. A., H. C. Brinton, and M. W. Pharo, III, "Compression of the Plasmasphere During Geomagnetically Disturbed Periods," GSFC X-621-67-559, Preprint. Also to be published in *J. Geophys. Res.*, 73, 1968.

ABSTRACT: Direct measurements of the thermal positive ions of hydrogen and helium have been obtained from positive ion mass spectrometers aboard the Orbiting Geophysical Observatories I and III. Observations made during 1965 and 1966 show distributions of H^+ and He^+ extending to altitudes as great as 40,000 kilometers, corresponding to a magnetospheric coordinate of $L = 8$. Typical H^+ profiles exhibit a comparatively gradual decrease in concentration with height within the plasmasphere.

The outer boundary of the plasmasphere, however, is characterized by an abrupt decrease in the ion concentration. This boundary or plasmopause, defined by the reduction of H^+ concentration to 5×10^0 ions/cm³ or less, is often quite sharp, with decreases in ion concentration of as much as an order of magnitude occurring within 250 kilometers of 0.1L. The position of the plasmopause is observed to move inward and outward from the earth in an inverse correlation with the planetary magnetic activity index K_p , indicating significant large scale expansion and contraction of the plasmasphere during periods of agitated magnetospheric conditions. The magnetosphere was generally disturbed during the period 7-9 July 1966, with importance 2 solar flares occurring on the 7th, 8th, and 9th, and a sudden commencement of an extensive magnetic storm at 21:03 UT on 8 July. At 11:56 UT on 9 July, the H^+ boundary was observed to be unusually low, at 3.3L and at a local time of 00:45 hours. This observation is in sharp contrast with measurements of the plasmopause on both preceding and succeeding orbits, when in the absence of flares and magnetic disturbance the plasmasphere was observed to expand to L values as high as 6, at nearly the same local time. These results are consistent with measurements during a lesser storm which occurred on 25 June 1966, and with earlier observations of the disturbed plasmasphere obtained from the OGO-I experiment. The apparent correlation between measurements of the hydrogen ion boundary and the "knee" whistler evidence of the plasmopause suggests that the mechanism responsible for the depletion of the ionization is effective along the lines of the magnetic field, extending well into the earth's inner atmosphere, to 1000 kilometers and below.

Taylor, H. A. Jr., H. C. Brinton, and M. W. Pharo, III, "Evidence of Contraction of the Earth's Thermal Plasmasphere Subsequent to the Solar Flare Events of 7 and 9 July 1966," presented at the COSPAR Meeting, London, July 1967. To be published in the Proton Flare Project issue of IQSY Annals.

ABSTRACT: Direct measurements of thermal H^+ and He^+ in the magnetosphere have been obtained from ion mass spectrometers on Orbiting Geophysical Observatories I and III. Typical H^+ profiles exhibit a gradual decrease in concentration with altitude within the plasmasphere, while the outer boundary of the plasmasphere is characterized by an abrupt decrease in concentration to 5 ions/cm³ or less. This boundary, the plasmopause, is observed to move inward and outward in an inverse correlation with the magnetic activity index K_p . The magnetosphere was disturbed during the solar flare period 7-9 July 1966, and on 9 July the plasmopause was observed to be unusually low, at $L = 3.3$. This observation contrasted with measurements of the plasmopause on both preceding and succeeding orbits, when in the absence of flares and magnetic disturbance the H^+ boundary was observed to expand to L values as high as 6. These measurements correlate well with "knee" whistler observations of the plasmopause.

B-16 (Bohn, Interplanetary Dust Particles)

Alexander, W. M., and J. L. Bohn, "Zodiacal Dust Measurements in Cis-Lunar and Interplanetary Space from OGO-III and Mariner IV Experiments between June and December 1966," presented at the 10th COSPAR Meeting, London, 1967.

ABSTRACT: New measurements of the flux of interplanetary dust particles in cislunar and interplanetary space have been obtained from experiments on the OGO-III and Mariner IV spacecraft. The major portion of the OGO-III measurement was made between 50,000 km and 110,000 km from the surface of the earth. The 1966 Mariner IV measurement was made over a heliocentric distance of 1.1 A. U. to 1.25 A. U. The OGO-III measurement represents the first measurement in cis-lunar space since Pioneer I and only measurement which repeatedly sampled the cis-lunar dust particle flux over a considerable period of time. For the first time, the Mariner IV measurement provides a second data sample over the same heliocentric distance in the zodiacal dust cloud by the same instrumentation. The results of these measurements are interpreted in terms of the recent hypervelocity calibration data and thermal effect studies and then compared to the previous satellite and space probe measurements.

Bohn, J. L., W. M. Alexander, and W. F. Simmons, "Results of Studies of Thermal Gradient Effects on Ceramic Transducer Sensors Used in Cosmic Dust Experiments," presented at the 10th COSPAR Meeting, London, 1967.

ABSTRACT: An extensive study of thermal gradient and temperature effects on ceramic transducer sensors used in cosmic dust experiments on rockets, satellites and deep space probes has been conducted. The transducers used in the tests were sensors from experiments on Explorer I, Pioneer I, Vanguard III, Explorer VIII, Mariner II, Mariner IV, OGO's I, II and III, Surveyor Lander and AIMP-E spacecraft. The sensors were subjected to temperatures over a range of $-20^{\circ}\text{C} \leq t \leq +46^{\circ}\text{C}$, and both positive and negative thermal gradients (t_{gd}) over a range of $0.01^{\circ}\text{C/m} \leq t_{\text{gd}} \leq 2.2^{\circ}\text{C/m}$. More than 350 transducer thermal cycles were conducted using the various transducer types of the above space experiments and simulating the different thermal conditions experienced by the sensors. The data from these tests show that thermal noise from the transducers has not been a major source of false data from the above experiments. The results of these new studies are discussed and interpreted with respect to the data from all previous dust particle experiments and other thermal studies.

B-17 (Helliwell, VLF Noise and Propagation)

Angerami, J. J., and R. L. Smith, "Ducted Whistlers on OGO-I and III," presented at the AGU Meeting, Washington, D. C., Vol. 48, No. 1, 88, March 1967.

ABSTRACT: Ducted Whistlers received at OGO-I and III present frequency-time characteristics that change discretely with time, corresponding to the motion of the satellite through different ducts of field-aligned enhancements of ionization. It is therefore possible to identify the ducts traversed and measure their sizes and spacings. Whistler data collected by OGO-III on June 15, 1966, between 4.5 and 5 Earth radii near the equatorial plane in the nightside of the Earth, will be presented as evidence for several field-aligned ducts, with widths ranging between 200 and 400 km at the satellite. Although the duct theory of whistler propagation has been supported in the past by VLF data collected by ground stations, the results reported in the present paper represent the first direct evidence of ducts beyond 3 Earth radii. Within the inner ducts there is observed leakage of the higher frequency portions of whistlers traveling in outer ducts. The frequency above which the leakage is observed is approximately half the local gyrofrequency, in accord with the prediction of the ray theory of ducting. It will be shown that the time delays and nose frequencies of the ducted fractional hop whistlers are in good agreement with the calculations if the magnetic field measured at the satellite is used, rather than the Jensen and Cain field, which was about 6% higher at the time considered. Simultaneous VLF recordings at a ground station were used as reference for measurement of the actual time delays.

Angerami, J. J., and R. L. Smith, "Satellite Observations of Whistler Ducts," presented at the 1967 Spring URSI Meeting, May 23-26, 1967, Ottawa, Ontario, Canada.

ABSTRACT: Although the duct theory of whistler propagation has been supported in the past by VLF data collected at ground stations, no direct evidence of the presence of such ducts has been available. The results reported in the present paper constitute the first direct experimental evidence of whistler ducts in the outer magnetosphere.

Ducted whistlers received at the high altitude OGO satellites are characterized by a frequency-time spectrum which changes discretely with time, corresponding to the motion of the satellite through different ducts of field aligned enhancements of ionization. It is therefore possible to identify the ducts traversed, and to measure their sizes and spacings.

The whistler data collected by OGO-III on 15 June 1966 between 4.5 and 5 earth radii near the equatorial plane on the nightside of the earth will be presented as evidence for several field aligned ducts. The duct widths range between 200 and 400 kilometers at the satellite. The higher frequency portions of whistlers traveling in the outer ducts are observed to leak into the inner regions. The frequency above which the leakage is observed is approximately half the local gyrofrequency, in accordance with the predictions of the ray theory of ducting.

Simultaneous VLF recordings performed at a ground station enabled the identification of the lightning sources for the whistlers received at the satellite, and measurement of the corresponding time delays. Both the time delays and the nose frequencies of the ducted fractional hop whistlers were found to be in good agreement with the calculations when the magnetic field measured at the satellite was used. During these observations, the Jensen and Cain field was 6 percent higher than the measured values. The K_p index was very close to zero for the preceding two days.

The results of a ray tracing showing the trapping and leakages related to the field aligned ducts will be shown and compared with the observations.

Carpenter, D. L., C. G. Park, and H. A. Taylor, Jr., "Multi-experiment Detection of the Plasmopause," submitted to the AGU for the Washington, D. C. meeting in April 1968.

ABSTRACT: Three independent means of detecting the plasmopause have been compared: 1) OGO-I and OGO-III mass spectrometer data on proton density; 2) broadband VLF recordings (0–12.5 khz) on OGO-I and OGO-III, 3) whistlers recorded at ground stations Eights and Byrd, Antarctica, near the 90°W meridian. (In the OGO VLF data, plasmopause crossings appear as abrupt changes in whistler activity, often accompanied by noise bands of limited duration.) The study included six OGO-I passes during May and June 1965 and the outbound OGO-III pass of 5 July 1966. Satellite plasmopause crossings occurred between 0730 and 2250 LT and between 17° and 42° geomagnetic latitude. The observed magnetic shell parameter of the plasmopause varied from 3.2 to 5.5 R_E . Simultaneous ground and satellite recordings with a local-time separation of about 1 hour show agreement on the plasmopause radius within experimental error of $\pm 0.2 R_E$. For larger local-time separations, the measurements agree well with the expected 3-dimensional properties of the plasmasphere. On OGO-I, inbound on 9 June 1965, and on OGO-III, outbound on 5 July 1966, plasmopause crossings detected by the onboard VLF receiver and mass spectrometer agreed within $< 0.1 R_E$ in plasmopause radius. These results also agreed with available ground whistler measurements. The findings of agreement between the ground whistler data and the satellite H^+ data should not be generalized, but appear to apply to at least a large class of OGO orbits.

Helliwell, R. A., "On the Generation of Discrete VLF Emissions," presented at the 1967 Spring URSI Meeting, May 23–26, 1967, Ottawa, Ontario, Canada.

ABSTRACT: Some of the spectral forms (e.g. 'inverted' hook) of discrete VLF emissions are not explained satisfactorily by current theories of generation based simply on gyroresonance between energetic streaming electrons and whistler-mode waves traveling in the opposite direction. An extension of the gyroresonance idea is proposed in which the *spatial variations* of the electron gyrofrequency and the Doppler-shifted wave frequency are required to be equal. The coupling time between a resonant electron and the wave is then maximized and hence the output wave intensity is maximized. Application of this condition leads directly to an expression for the time rate of change of emission frequency in terms of the location of the interaction region. Observed slopes of emission traces give locations close to the geomagnetic equator.

An approximate analysis of the postulated interaction process leads to a theorem which states that: the wave magnetic field intensity is limited to a value less than that at which the bunching time approximately equals the resonance time. When the input particle flux exceeds the value required to account for this limiting value of wave intensity, the interaction region drifts downstream. If the interaction begins on the falling-tone or 'upstream' side of the equator, positive drift carries the interaction across the equator into the rising tone region, giving rise to the well known 'hook' shape. Reversal of the drift, resulting from wave damping, or other factors, carries the interaction back across the equator, giving rise to the inverted hook, a shape not explained by previous theories. Combinations of positive and negative drifts can explain the principal emission forms.

Helliwell, R. A., "A Theory of Discrete VLF Emissions from the Magnetosphere," *J. Geophys. Res.* 72, 4773–4790, October 1967.

ABSTRACT: Some of the spectral forms (e.g. 'inverted' hook) of discrete VLF emissions are not explained satisfactorily by present theories of generation based simply on gyroresonance between energetic streaming electrons and whistler-mode waves traveling in the opposite direction. An extension of the gyroresonance idea is proposed in which the *spatial variations* of the electron gyrofrequency and the Doppler-shifted wave frequency are matched. The coupling time between a resonant electron and the wave is then maximized, and hence the output wave intensity is maximized. Application of this condition leads directly to an expression for the time rate of change emission frequency in terms of the location of the interaction region. An approximate analysis of the postulated interaction process leads to a theorem that states: The magnetic field intensity is limited to a value less than that at which the bunching time approximately equals the resonance time. When the input particle flux exceeds the value required to account for this limiting value of wave intensity, the interaction region drifts downstream. If the interaction begins on the falling-tone or 'upstream' side of the equator, positive drift carries the interaction across the equator into the rising-tone region, giving rise to the well known

'hook' shape. Reversal of the drift, resulting from wave damping or other factors, carries the interaction back across the equator, giving rise to the inverted hook, a shape not explained by previous theories. Combinations of positive and negative drifts can explain the principal emission forms. The triggering delay and offset frequency of artificially triggered discrete VLF emissions can be explained by the theory.

Heyborne, R. L., "Observations of Whistler-Mode Signals in the OGO Satellites from VLF Ground Station Transmitters," presented at the December 1966 Joint URSI-IEEE Meeting, Palo Alto, California, Stanford University Radioscience Technical Report SU-SEL-66-094, Nov. 1966.

ABSTRACT: In the ionospheric plasma, electromagnetic propagation is possible at frequencies below the plasma frequency and the electron gyrofrequency. This mode of propagation is commonly known as the whistler mode.

Amplitude calibrated receivers aboard two satellites (OGO-I and OGO-III) are used to receive signals propagating in the whistler mode from U. S. Navy VLF stations on the ground. Existing theory is utilized to calculate the expected intensities of these signals. Measured and calculated intensities are then compared.

The two satellites effectively sub-divide the whistler mode path into two main parts: (1) the earth-ionosphere waveguide loss, the boundary and excitation loss, and the absorption loss through the ionosphere to the altitudes of OGO-II and (2) losses due to divergence of the signal between OGO-II and the higher altitudes of OGO-I plus any additional absorption above OGO-II. These data are utilized to determine more precisely the major features and loss characteristics of whistler-mode paths inferred from previous experiments, and to determine the accuracy of attenuation rates predicted earlier by theoretical means.

It is concluded that the average intensity of VLF whistler-mode signals in the magnetosphere may usually be predicted to an accuracy of ± 10 db by the use of available models and existing theory. This study strongly supports present understanding of the major features of whistler-mode propagation which until now has been based largely on theoretical developments and experimental observations of naturally occurring phenomena.

Several new observations have been made. These include:

(1) A Northern hemisphere latitudinal cutoff of VLF signals. Signal intensities have been observed to decrease as much as 40 db as OGO-II moves from approximately 59° to 60° Northern geomagnetic latitude. Signals are seldom observed at latitudes above the cutoff region. There is evidence that the cutoff is more pronounced during the daytime and when the geomagnetic planetary K_p index is high. It is hypothesized that the $N\nu$ product in the D and E regions of the ionosphere increases rapidly with latitude near the cutoff region. The evidence suggests that the observed cutoff is consistent with an absorption explanation.

(2) Strong enhancements of VLF signals near the antipodes of VLF transmitters. Enhancement factors as high as 25 db have been observed when the satellite flies within 200 km of the antipode. Enhancements have also been observed near the magnetic conjugate of the antipode.

(3) A pronounced dip in the intensity of VLF signals over the geomagnetic equator. Seen at all longitudes, both daytime and nighttime, the magnitude of the equatorial dip is typically 12 to 20 db during the daytime and 5 to 10 db during the nighttime. The observation is explained on the basis of absorption.

(4) A band of intense noise at 18 kHz around both polar regions. The intense noise is observed in a band 3 to 11 degrees wide centered near 75 degrees geomagnetic latitude. Occurrence of the noise exhibits seasonal dependence with local summer rates higher than winter. Although there is evidence that the intense noise is more likely to be observed during magnetically disturbed periods, fluctuations in the noise magnitude can not be explained by fluctuations in the K_p index.

Katsufakis, J., "Preliminary Results of the Stanford University VLF-LF Experiment aboard the OGO-III Satellite," paper presented Stanford University Electronics Research Review, Stanford University, Stanford, Calif. August 18-19, 1966.

ABSTRACT: The OGO-III satellite was launched from Cape Kennedy on 7 June 1966 at 0248 GMT into an orbit with a 30.9° inclination, a 121,937 km apogee, and a 273 km perigee.

The highly elliptical OGO-III orbit allows the observatory to traverse the radiation belts and to make a series of geophysical measurements from the region near the earth and through the

magnetosphere to interplanetary space. The payload consists of 20 experiments designed for the study of charged particles, measurement of magnetic fields, and observation of various ionospheric and radio astronomical phenomena.

The following observations from the VLF/LF experiment will be presented:

- 1) A marked and sudden increase in the whistler rate as the satellite, in bound from apogee, crosses the plasmapause.
- 2) The association between VLF bursts and rapid variations in the total magnetic field intensity.
- 3) The existence of strong VLF emission activity at great distances beyond the plasmapause.
- 4) An extremely high rate of whistler activity from the plasmapause to perigee.

Price, G. H., "Propagation of Electromagnetic Waves into Anisotropic Media from an External Point-Dipole Source," *Radio Science*, 2, (New Series) 607-618, June 1967.

ABSTRACT: A formal solution to the problem of determining the fields generated by an infinitesimal, arbitrarily oriented, electric-dipole source located in an isotropic medium bounded by parallel plane-stratified, anisotropic media is derived.

Rorden, L. H., L. E. Orsak, B. P. Ficklin, and R. H. Stehle, "Instruments for the Stanford University/Stanford Research Institute VLF Experiment (4917) on the EGO Satellite," Stanford Research Institute Instrument Report, May 1966.

Smith, R. L., and J. J. Angerami, "Whistler Propagation in Magnetosphere Ducts," presented at Conjugate Point Symposium, Boulder, Colorado, June 12-15, 1967.

ABSTRACT: This paper reviews some of the theories of propagation of whistlers in field aligned ducts and their relation to recent observations. A number of the features of propagation deduced from the ray theory approach have been verified by recent ground and satellite observations. These observations in turn have led to further ray tracing studies which explain some interesting high frequency leakage effects and suggest an indirect experimental determination of duct dimensions and enhancement factors.

B-18 (Haddock, Radio Astronomy)

Graedel, T. E., "Initial Results Radio Astronomy-Experiment No. 18, OGO-III," University of Michigan Preliminary Report UM/RAO Report 67-9, Oct. 1967.

ABSTRACT: The University of Michigan Radio Astronomy Observatory is currently engaged in analyzing data from its experiment aboard the spacecraft OGO-III (OGO-B). This experiment is designed to measure a portion of the dynamic radio spectrum of solar and jovian burst activity. The frequency range covered by the radiometer is 2-4 MHz. This report discusses and illustrates typical features which are observed by the satellite in the frequency range specified above, and comments briefly on some of the scientific consequences and potentialities of the experiment.

B-20 (Wolff, Gegenschein Photometry)

Wolff, C., "The Optical Environment about the OGO-III Satellite," *Science*, 158, 1045, 1967.

ABSTRACT: An upper limit to the brightness of the daytime sky near a large unmanned satellite has been obtained which is some 30 times less than the darkest daytime sky yet reported by an astronaut. However, there still remains the danger that this background light (less than 5×10^{-13} as bright as the sun) will interfere with observations of the solar corona and zodiacal light.

OGO-III TECHNICAL PAPERS

Blair, W. E., "Resonances in the Driving-Point Impedance of an Electric Dipole in the Ionosphere," Stanford Research Institute Technical Report 1, March 1967.

ABSTRACT: The resonances in the driving-point impedance of a center-fed cylindrical electric dipole imbedded in the ionosphere are analyzed. The ionospheric model is a lossy, anisotropic, homogeneous neutral plasma containing various ionic constituents. It is found that there are zeros in the reactance at the upper and lower hybrid frequencies and poles at the electron and ion gyrofrequencies. These critical frequencies are independent of antenna length and orientation (parallel or perpendicular to the earth's magnetic field) to the first-order approximation. It is shown that pole-zero frequencies could be used to determine the earth's magnetic field strength, electron density, and ion masses and densities at any point in the ionosphere at which the impedance was measured.

Blair, W. E., and B. P. Ficklin, "Summary of Digital Data-Processing Systems for the OGO SU/SRI Very-Low Frequency Experiments," Stanford Radioscience Laboratory Summary Report, July 1967.

ABSTRACT: This report summarizes the computer digital data-processing techniques for the Stanford University/Stanford Research Institute (SU/SRI) very-low-frequency (VLF) radio noise and propagation experiments aboard the OGO satellites. Specifically, the processing system outputs for the VLF experiments aboard OGO-I (A-17), OGO-II (C-02), and OGO-III (B-17) are briefly described. These outputs are contiguous 16-mm cine films on which the data are plotted and pertinent satellite and geophysical parameters are listed. The cine films are described, and the advantages of the system for compacting, scanning, accessing, and analyzing the data are stated.

Britner, R. O., "Orbiting Geophysical Observatory OGO-B NASA-GSFC Operations Plan 4-66," April 1966, GSFC X-513-66-128, Preprint.

ABSTRACT: The primary objective of the Orbiting Geophysical Observatory (OGO) program is to conduct large numbers of significant and diversified geophysical experiments to obtain a better understanding of the earth-sun relationships and of the earth as a planet.

The secondary objective of the OGO program is to develop a standardized observatory-type spacecraft which has the basic structure and subsystem design to allow its configuration to be used repeatedly to carry large numbers of easily integrated scientific experiments in a wide variety of orbits.

The third mission in the OGO program is the OGO-B, and Eccentric Orbiting Geophysical Observatory (EGO). The objective of OGO-B is to make experimental measurements over a wide range of distances from the near-earth region where sounding rockets and low altitude satellites are effective to extra-terrestrial space where the earth's magnetic field and atmosphere no longer alter the characteristics of the phenomena to be observed. The experiments selected for the OGO-B and later missions will extend our understanding of energetic charged particles, low-energy charged particles, magnetic and electric fields, micrometeorites, ultraviolet scattering near the earth, X-rays and gamma rays, VLF phenomena, radio noise phenomena, and ionospheric aeronomy phenomena in the region near the earth. This mission is similar to the OGO-A (OGO-I) in orbital parameters and in the experiment selection.

Ficklin, B. P., R. H. Stehle, C. Barnes, and M. E. Mills, "The Instrumentation for the Stanford University/Stanford Research Institute VLF Experiment (B-17) on the OGO-III Satellite," Stanford Research Institute Supplemental Report, May 1967.

ABSTRACT: The Stanford University/Stanford Research Institute VLF Experiment B-17 instrumentation launched on the OGO-III satellite on 4 June 1966 is a modified version of the Experiment A-17 instrumentation launched on the OGO-I satellite in 1964. Both the experiment on OGO-I and that on OGO-III measure the VLF noise in the satellite orbits (from 200 Hz to 100 kHz in contiguous narrow bands, and from 300 Hz to 12.5 kHz in a single broad band), the magnitude of the impedance of a magnetic dipole, and the relative phases of signals from ground transmitters. In addition, noise measurements by Experiment B-17 extend down to 15 Hz—to permit observation of proton whistlers to altitudes up to four earth radii. Experiment B-17 also allows observation of electrical fields, as well as magnetic fields, on command, and measures the magnitude of impedance of an unsymmetrical electrical dipole in the magnetoplasma. This supplemental report describes the physical and electrical characteristics of the Experiment B-17 instrumentation and presents prelaunch calibration data.

Frank, L. A., "Low-Energy Proton and Electron Experiment for the Orbiting Geophysical Observatories B and E," University of Iowa Report 65-22, July 1965.

ABSTRACT: The instrumentation and calibrations of the University of Iowa low-energy proton and electron experiment for the Orbiting Geophysical Laboratories (OGO) B and E are described. The experiment utilizes cylindrical curved-plate electrostatic analyzers to provide measurements of the differential energy spectrums of protons and electrons within and in the vicinity of the earth's magnetosphere. Continuous channel multipliers (Bendix 'Channeltrons') are used to count individual charged particles accepted by the analyzers and provide the instrument with a dynamic range in proton and electron intensities extending from 10^4 to 10^{10} $(\text{cm}^2\text{-sec-sr})^{-1}$ in a given energy bandpass of the electrostatic analyzer. The widths of the energy bandpasses of the electrostatic analyzers are sufficiently wide to cover the entire energy range extending from 90 eV to 70,000 eV (protons and electrons separately) in 14 voltage steps on the curved plates. The four electrostatic analyzers (two analyzers each for protons and electrons covering the above energy range) complete with signal conditioner, high-voltage power supplies, and thermal shell require an average power of 2 watts and an instrumental weight of 6.3 pounds.

Kane, S. R., K. A. Pfitzer, and J. R. Winckler, "The Construction, Calibration and Operation of the University of Minnesota Experiments for OGO-I and OGO-III," University of Minnesota Technical Report CR-87, September 1966.

ABSTRACT: This report presents our final and best estimates of the response characteristics of the ionization chamber and electron spectrometer experiments flown on the OGO-I and OGO-III satellites. These experiments are officially designated:

4909-MB (spectrometer)
4909-EP4 (ion chamber).

Kendall, D. E., et al, "OGO-B Project Operations Requirements," April 1966, NASA 2324-6003-RU000.

ABSTRACT: The purpose of this document is to define the operational requirements for the OGO Project, specifically as they apply to the OGO-B satellite. The operational concepts contained herein reflect the capabilities of the entire OGO system, including observatory, Space Tracking and Data Acquisition support communications and specialized NASA facilities.

Montgomery, H., and C. Herron, "Shades of OGO-B (S-49a)," April 1965, GSFC X-640-65-150, Preprint.

ABSTRACT: This is the third of a series of shadow studies of OGO satellites. This particular satellite will be the second Eccentric Orbiting Geophysical Observatory (EGO).

The Orbiting Geophysical Observatory (OGO) consists of a main box, the solar array, and the orbital plane experiment package (OPEP). Experiments may be appended to any of the three main component parts either directly or on booms. As many as fifty experiment packages may be carried on the OGO spacecraft. The solar array and the OPEP may rotate relative to the main box. The main box and the solar array are considered as casting shadows and carrying experiments; the OPEP is considered only as carrying experiments. Heat inputs include direct solar, reflected solar, and Earth emitted heat flux. If the experiment is shielded from the Sun by the Earth, the main box, or the solar array, the solar input to that particular experiment is set to zero. If an experiment is in the eclipse of the Earth, the reflected solar (as well as the direct solar) heat input is set to zero. However, the effects of shadowing of an experiment from the Earth by the main box or by the Solar array is not considered in the computation of the solar reflected or Earth emitted heat inputs to that particular experiment. Shadow data are presented for the OGO-B for a launch data of November 1, 1965, at 0.0 hours U.T.. The heat input data are for an EPOCH time of December 30, 1965, at 17.5 hours U.T. The injection elements and launch time are from Reference 1.

NASA Press Kit News Release 66-132, May 1966, "Geophysical Observatory Launch May 31 (OGO-B)."

Quann, J. J., "Data Processing Plan for Eccentric Orbiting Geophysical Observatory (OGO-B)," March 1966, GSFC X-564-66-101, Preprint.

ABSTRACT: The OGO-B spacecraft, depicted in Figure 1, will carry into a highly eccentric orbit about the earth, a large number of varied geophysical experiments. A greater understanding of the earth, and of earth-sun relationships will be obtained from these.

As the third mission of the OGO program, the OGO-B will be launched by an Atlas-Agena B vehicle from the Atlantic Missile Range and injected into an eccentric orbit of approximately 31 degrees inclination. The spacecraft weighs about 1000 pounds, of which 150 pounds are allocated for the experiments. The orbit has a nominal perigee of 150 nautical miles, a nominal apogee of 80,000 nautical miles, and a period of 63.3 hours. The orbit allows the OGO-B to traverse the radiation belts twice during each orbit and to make geophysical measurements from the region near the earth to cislunar space. A mission lifetime of one year is expected.

Stewart, D. J., and J. J. Fleming, "Orbit Determination Plan for the Satellite OGO-B," May 1966, GSFC X-547-66-191, Preprint.

ABSTRACT: The primary objective of the Orbiting Geophysical Observatory (OGO-B) Satellite is to conduct large numbers of significant, diversified geophysical experiments for obtaining a better understanding of the earth-sun relationships and the earth as a planet. The secondary objective of the program is the development and operation of a standardized observatory-type oriented spacecraft, consisting of a basic structure and sub-systems design which can be used repeatedly to carry large numbers of easily integrated scientific experiments in a wide variety of orbits. As a design objective for the standardized spacecraft, it is desired that the spacecraft be capable of operation for a period of one year, during which the orientation of portions of the spacecraft toward the sun, the earth, and in the orbital plane can be accomplished.

The observatory is to be launched from the Eastern Test Range along an azimuth of 104 degrees. Nominal values for the principal elements of the orbit are as follows:

Period, minutes	2939.07
Perigee Height, s.m.	171
Perigee Height, km.	275
Apogee Height, s.m.	76370
Apogee Height, km.	122906
Inclination, deg.	30.99
Semi-major axis, km.	67969
Eccentricity	0.9021
Argument of Perigee, deg.	313.08
Right ascension of ascending node, deg.	87.10
Mean anomaly, deg.	0.07

The world map showing the first two orbits of the OGO-B is given in attachment 1.

The observatory will be separated from the Agena second stage about 56 minutes after lift-off.

Wiggins, E. T., "Operations Summary Report OGO-III," Report No. 2338-6009-RU000, June 1966.

OGO-IV DESCRIPTION OF EXPERIMENTS

D-01 RADIO ASTRONOMY, Dr. F. T. Haddock, U. of Mich.

The prime objective of this experiment is to map the brightness distribution of 2.5 Mc cosmic radio noise.

Other objectives are to observe certain ionospheric phenomena, one of which is a form of presumably locally generated noise in the topside ionosphere. Although the origin of this noise is not yet clear, it is possibly caused by Cerenkov radiation. Finally, it should be possible to detect tenuous ionized interstellar hydrogen by its absorption effects.

Instrumentation consists of a common preamplifier driving three separate output channels: 2.5 Mc and 2.0 Mc receivers and an antenna impedance measurement channel. A 60-foot tubular antenna of approximately 0.56 inches diameter will be deployed from the SOEP after the observatory is in orbit.

D-02 VLF NOISE AND PROPAGATIONS, Dr. R. A. Helliwell, Stanford U.

The objectives of this experiment are to study VLF propagation, properties of the ionosphere, the origin of VLF ionospheric noise, and a synoptic noise survey in the frequency range 0.03-100 kc. The phenomena to be studied include: the terrestrial noise produced from such atmospheric phenomena as lightning noise, VLF emissions generated by moving charged particles, and the propagation of VLF signals from low frequency ground stations. As a result of a similar experiment flown on OGO-I and II the frequency limit of the OGO-III and OGO-IV experiment was lowered and provision included for measurement of electric fields and electric antenna impedance. The earlier flights of this experiment have provided information on a new noise source deep in the magnetosphere, on proton and helium whistlers, on ducted and non-ducted propagation, and on propagation asymmetries.

The experiment instrumentation consists of five receivers: three step-frequency receivers, each covering one octave of the 0.2 to 100 kc range, a preamplifier which detects 0.03 to 0.20, a 0.2 to 12.5 kc broadband receiver, and a tunable narrowband receiver (14.7 to 26.1 kc) for reception of Navy VLF transmitters. The antenna, a 9.5 foot wide hexagonally shaped tube located at the end of a 20-foot boom, is to be released and inflated after the observatory is in orbit. The receivers and other instrumentation are located in the main body.

D-03 WHISTLERS AND AUDIO-FREQUENCY ELECTROMAGNETIC WAVES, Prof. M. G. Morgan, Dartmouth College.

The effects of the ionosphere on the propagation of whistlers and other audio-frequency (500 cps to 18 kc) electromagnetic waves of natural origin will be studied by this experiment. Problems to be studied included the question of the height of reflection of whistler echo trains and the variation of the ionospheric transmission loss of whistler-mode waves with time and frequency.

To meet these objectives, most of the data from the observatory will be subjected to a detailed comparison with observations made simultaneously at a network of ground-based whistler stations.

A simple broadband (500 cps to 18 kc) receiver with adjustable gain is used. In orbit, a 10-foot dipole antenna will be deployed from a short boom.

D-05 LOW-FREQUENCY MAGNETIC FIELD FLUCTUATIONS, Dr. E. J. Smith, JPL

The scientific objective is to investigate the naturally occurring magnetic field fluctuations in the low-audio and sub-audio frequency ranges (0.01-1000 cps). This includes signals which have been observed at the surface of the Earth and which are known to originate in or above the ionosphere; such as micropulsations (0.03 to 0.1 cps), hydromagnetic emissions (1 to 5 cps), and ELF emissions (200 to 1000 cps). It may also be possible to detect terrestrial ELF radio noise associated with lightning. Other signals which have not been observed at the surface of the Earth but which may reasonably be expected to occur in or above the ionosphere include magnetic variations associated with the intrusion of plasma clouds in the vicinity of the auroral zone, traveling ionospheric disturbances, and signals arising from the motion of the observatory with respect to magnetic fields created by the polar and equatorial electrojets. A similar experiment aboard the previous three OGO's has provided evidence of high frequency magnetic fluctuations near the magnetospheric boundary, at the bow shock and in the auroral zones.

The magnetometer is composed of a triaxial array of search coils situated at the end of one of the long booms for isolation from magnetic noise generated by the spacecraft and other experiments. This type of magnetometer is insensitive to fixed (d-c) magnetic fields, since a search coil basically consists of many

thousands of turns of copper wire wound on a high μ core. An output from each of the three coils is proportional to the time rate of change of the ambient magnetic field.

D-06 WORLD MAGNETIC SURVEY, Dr. J. C. Cain, GSFC

A Rubidium Vapor magnetometer is used to obtain accurate scalar field measurements. Combined with vector field data extrapolated from surface and airborne measurements, these data will provide for a continued refinement of the mathematical description of the Earth's main field and a measurement of the contribution of the main field to the total magnetic field at any point in space. Time variances of the field will also be studied to derive the diurnal and storm variations as seen above the ionosphere. The orbit of the observatory should allow a comprehensive determination of the solar daily variations during both quiet and disturbed conditions as well as a study of such phenomena as the equatorial and auroral electrojets.

Initial global magnetic survey data were obtained with similar instrumentation aboard OGO-II as part of the United States' commitment for the IQSY-World Magnetic Survey. The OGO-IV experiment should enhance these results, should allow some identification of short-period (several years) secular changes, and should, because of solar cycle variations, provide further insight on storm-like disturbances.

The magnetometer, located at the end of the other long boom, employs optical pumping of Rubidium vapor cells. Accuracy is ± 1 gamma.

D-07 COSMIC RAY AND POLAR IONIZATION STUDY, Dr. H. R. Anderson, Rice U.

The primary objective of this experiment is to study the behavior of cosmic rays in the Earth's magnetic field and to correlate this information with that obtained with the similar instruments mounted on balloons released at various latitudes.

Instrumentation consists of a 5-inch integrating ionization chamber filled with argon. The chamber's output voltage excursions are related to the incidence of cosmic radiation and the time interval between excursions of the intensity of radiation. The minimum detectable particle energies are 10 Mev for protons, 40 Mev for alpha particles, and 0.5 Mev for electrons.

D-08 ENERGETIC PARTICLES SURVEY, Dr. J. A. Simpson, U. of Chicago

Protons in the energy spectrum from 0.5 Mev to 40 Mev and alpha particles between 2 Mev and 160 Mev are investigated. In a continued study of cosmic radiation, the objective of this experiment is to search for an extension of the spectra of untrapped protons and helium nuclei to very low energies and low intensity during the period of minimum solar activity and to provide evidence whether the radiation is of solar or galactic origin. These data and data obtained during solar flare events will be studied to determine the characteristics of storage and propagation of particles as modulated by the interplanetary magnetic fields during a relatively active Sun. Radiation belt proton and alpha fluxes at low altitude, and auroral protons in the energy range of the detectors will also be measured.

Two orthogonal telescopes are located in the mainbody on the anti-Earth side of the observatory. The vertical telescope consists of two solid state detectors mounted in a scintillator cup. Pulse height analysis and total count rate for various coincidence combinations yield the desired parameters. The horizontal telescope consists of a single solid state detector to measure proton-alpha flux isotropically incident to the Earth's magnetic field.

D-09 GALACTIC AND SOLAR COSMIC RAY STUDY, Dr. W. A. Webber, U. of Minn.

Data collected by this experiment will directly allow the determination of the energy spectrum of both galactic and solar protons over the energy range from 40 Mev to 1 Bev as well as other particles over a comparable energy per nucleon range. The direction of the particle influx will also be determined. By using the Earth's field as a magnetic analyzer, the energy range is extended to 30 Bev for protons over the equatorial regions. Also, the experiment functions as a high counting rate monitor for all radiation capable of penetrating 0.5 gm/cm^2 .

The experiment consists of a mainbody detector oriented in the anti-Earth direction. The sensing device is composed of a scintillation crystal and a combination scintillation and Cerenkov detector. The minimum detectable energy is governed by the crystal thickness and the amount of shielding. All particles

capable of producing a detectable light pulse are counted by the scintillation crystal. This provides a monitor for the total radiation. Otherwise, only coincident detector outputs are analyzed in order to measure the energy spectrum.

D-10 TRAPPED AND PRECIPITATING PARTICLES, Dr. J. A. Van Allen, U. of Iowa

This experiment includes a comprehensive latitude and temporal study of the intensities and energy spectra of electrons and protons precipitating into the Earth's upper atmosphere (75 ev to 7500 ev). Information will also be obtained on the spatial, angular and temporal distribution of geomagnetically trapped proton and alpha particles.

The experiment is comprised of three sensors mounted on a short boom. A cylindrical electrostatic analyzer with Channeltron (channel electron multiplier) detectors is used to detect low energy protons and electrons both separately and simultaneously. Electronic bias levels applied to two, thin, totally depleted, shielded, surface barrier silicon detectors provide four channels for measuring trapped alphas in the energy range of 1.5 to 10 Mev; and trapped protons and alphas in the energy range of 0.25 to 20 Mev and 0.40 to 200 Mev, respectively. A single thin window Geiger tube is provided for an integral measurement of electron flux above 40 Kev.

D-11 LOW ENERGY AURORAL PARTICLES, Dr. R. A. Hoffman, GSFC

Low energy auroral particles will be studied through high resolution measurements of the energy spectra and pitch angle distribution of electrons and protons (0.5 to 20 kev). Knowledge of low energy electrons and protons will contribute to understanding auroral and sub-auroral zone phenomena. Eight channel electron multipliers with cylindrical curved plate electrostatic analyzers are positioned on a short boom to locate four detectors (center energy: 0.55 kev, 1.0 kev, 4.3 kev, 10.5 kev) radially away from Earth and three detectors (center energy: 3.2 kev) at angles of 30, 60, and 90 degrees. The eighth detector will obtain background counts due to energetic particles and x-rays. By ground command, the polarity of the voltage on the analyzer plates is reversed allowing measurement of either electrons or protons.

D-12 AIRGLOW AND AURORAL STUDY, Prof. J. Blamont, U. of Paris and GSFC

The objective of this experiment is the observation of airglow and auroral activity by photometric measurement of emissions at the following wavelengths: 2630 Å (ultraviolet airglow); 3914 Å (visible aurora—molecular nitrogen ion emission); 5577 Å (airglow and aurora—green atomic oxygen emission); 5890 Å (airglow—sodium emission); 6225 Å (Hydroxyl radiation); 6300 Å (red atomic oxygen).

Photometers are mounted in the main body and the Orbital Plane Experiment Package (OPEP). All of the above spectral lines are sensed by the main body photometer oriented in the Earth direction. The 6300 Å line is also observed in the anti-Earth direction and by the OPEP photometer. In the main body photometer, the incident light is alternately directed through six filters corresponding to the six wavelengths by an automatic stepping mirror system.

The mirrors can be commanded to remain in any of the spectral positions for a more comprehensive study of the distribution of a particular line. The OPEP photometer views towards Earth and projects the light through a 6300 Å filter. A mirror scan system and OPEP rotation provide a two-dimensional sweep from the observatory's horizon to 30° in the direction of the Earth over an angular range of +110 deg.

D-13 LYMAN-ALPHA AND ULTRAVIOLET AIRGLOW STUDY, Dr. P. W. Mange, NRL

This experiment will measure the flux of scattered hydrogen Lyman-Alpha radiation (1216 Å) incident upon the Earth and the Earth albedo (ratio of reflected to incident radiation) at 1216 Å, 1230-1350 Å, and 1350-1550 Å. Measuring the excitation of ultraviolet fluorescence produced by particles provides an effective means of measuring the rate at which particles deliver energy to the atmosphere. A knowledge of the rate of energy input into the upper atmosphere as a function of time and location will greatly aid the understanding of both high altitude airglow emissions and of the origin of the electron component of the Van Allen belts. The Lyman-alpha measurement of atmospheric emissions can be related to spatial asymmetries in the atomic hydrogen content near the dissociation level, and will provide information concerning variations in the vertical transport of water vapor and methane.

Five ionization chambers and three cesium iodide photocells are used as detectors and are located in the main body. Two of the chambers are sensitive to Lyman-alpha radiation incident from the Earth and anti-Earth directions. The other six chambers are connected in two groups of three chambers to increase the sensitivity. Wavelength sensitivities are determined by window materials and the filler gas.

D-14 ULTRAVIOLET SPECTRA OF THE EARTH'S ATMOSPHERE, Dr. C. A. Barth, U. of Colo.

The scientific objective of this experiment is to measure the ultraviolet spectra of the Earth's upper atmosphere from 1100A to 3400A. These spectra will provide information on the nature and energy of the luminous particles in the aurora; the abundance and distribution of the molecular constituents in day-glow, atomic constituents in twilight glow, and the abundance and distribution of ozone.

The spectrometer consists of three basic parts: a telescope, monochrometer, and detectors. The telescope (Cassegrain) projects an image of the central portion of the Earth into an entrance slit of the monochrometer. The light is then separated by a ruled diffraction grating and projected onto an exit slit for selection of a minimum number of spectral lines for detection by photomultiplier tubes. The diffraction grating is automatically rotated to scan the spectrum.

D-15 NEUTRAL PARTICLES AND ION COMPOSITION STUDY, Prof. L. Jones, U. of Mich.

The objective of this experiment is to measure the ambient neutral gas and positive ion composition (1 to 50 AMU) of the atmosphere as a function of altitude and geographical position. The data will be an extension of composition measurements made primarily by sounding rocket techniques. Of prime interest is the dissociation and diffusive separation of the constituents of the atmosphere and the verification of a protonosphere.

The mass spectrometer utilized is the Paul massenfilter and is located in an OPEP. A varying quadrupole electrostatic field from four rods positioned 90° apart separates the various constituents of an incoming ionic gas into components of like charge-to-mass ratios. The separated components then drift out of the electrostatic field to a collector. The spectrometer alternates between positive ion and neutral particle measurements. Since neutral particles are insensitive to the electrostatic fields, a thermionic filament ionizes the ambient neutral particles before they enter the sensor.

D-16 POSITIVE ION COMPOSITION, H. A. Taylor, GSFC

This experiment will obtain high resolution measurements (± 1 AMU) of positive ion composition (1 to 45 AMU) within the Earth's lower ionosphere and the unexplored polar regions. These data will help identify and study suspected transition regions in the ionosphere where the predominant constituents may change.

Results of a similar experiment on previous OGO's have revealed a strong influence of the Earth's magnetic field upon the distribution of ions.

The instrument used is a Bennett RF mass spectrometer located in the OPEP. The spectrometer consists of a tube with a number of plane-parallel knitted grids mounted at right angles to the axis of the tube. A-C and D-C fields accelerate the ions down the length of the tube toward a collector. To reach the collector, the ions must pass through a retarding potential. Only those ions satisfying the velocity and phase conditions established by the fields will receive sufficient energy from the fields to pass the retarding potential, and impinge on the collector.

D-17 NEUTRAL PARTICLE STUDY, G. P. Newton, GSFC

This experiment utilizes a Bayard-Alpert ionization gauge to directly measure neutral particle temperatures and densities to observe variances with longitude, latitude, altitude, day-night and seasonal changes. The data obtained will extend the knowledge of both the structure of the atmosphere and its thermal equilibrium.

The gauge resembles a conventional triode except the grid is positive and the anode is a small central rod. Electrons emitted from one of three redundant filaments ionize the neutral particles by collision. The electrons are then attracted to the grid, which repels the positive ions toward a collector to produce a measurable collector current which is proportional to the number density of the particles inside the gauge. The sensor, located in an OPEP, is scanned about the velocity vector. The variance of gauge pressure with rotation provides a measure of the neutral particle velocity distribution from which the temperature can be deduced. The gauge is sealed by a cover which is ejected in the post-launch period.

D-18 MICROMETEORITES, Dr. C. S. Nilsson, SAO

This experiment is one of a series of similar OGO experiments designed to provide a basic measure and understanding of the dust particle environment of the Earth. The experiment on OGO-IV is designed specifically to measure the spatial density, velocity, and mass of dust particles in the mass range 10^{-13} to 10^{-9} grams. These measurements will be used to determine the orbits of these particles and to detect the existence of dust particle streams. Investigations of the importance of geomagnetic control on the dynamics of the dust particles and correlation of the various measurements with geophysical, geomagnetic and solar phenomena will also be attempted.

The particles are detected by four tubular detectors mounted on a short boom and aligned along the body axes of the observatory. An incoming particle first penetrates a thin film sensor which generates a plasma cloud used to start a 4 mc clock. The time-of-flight clock is stopped when the particle impacts on the rear sensor. This provides a measure of the velocity of the particle. A microphone attached to the rear sensor produces an output proportional to the momentum of the particle. Knowing the velocity, the mass of the particle can then be calculated. A knowledge of the orientation of the observatory defines the trajectory of the particle from which the approximate particle orbit can be computed.

D-19 IONOSPHERIC COMPOSITION AND SOLAR ULTRAVIOLET RADIATION, J. L. Donley, GSFC

The scientific objectives of this experiment are to measure the solar ultraviolet radiation intensity, charge particle intensity, ion composition and temperature, and electron temperature. Measurement of these parameters will provide a test of empirical models of density distributions, will provide information on the behavior of the $O^+ - He^+$ and $He^+ - H^+$ transition regions, and will provide input data to the equations of continuity which relate solar radiation to the characteristics of the atmosphere. Theories of temperature equilibrium will also be tested and contributions to theories of atmospheric heating are expected.

The experimental approach to both the ionospheric measurements and solar ultraviolet measurements involves a retarding potential technique. Two identical sensors are employed. The ionospheric sensor is located in an OPEP and the solar radiation sensor in a SOEP. Each sensor consists of three circular grids and a collector mounted in planar parallel geometry. Switching of bias voltages and application of a stepping retarding potential to the outer grids varies the ion or electron flux. The collector current as a function of bias voltage and the retarding potential yields the desired parameters. In the ultraviolet sensor, the outer grids repel ambient particles and a ramp voltage applied to the inner grid retards the emission of photoelectrons from the collector. The energy spectrum of emitted electrons can be related to the total ultraviolet flux.

D-20 SOLAR ULTRAVIOLET EMISSIONS, Dr. H. E. Hinteregger, AFCRL

The objective of this experiment is to monitor radiation intensities in the extreme ultraviolet (170A to 1700A) portion of the solar spectrum. It will provide needed information on intensity levels and the temporal variations of these levels for correlative studies of UV emissions with ionospheric and atmospheric phenomena.

A scanning, grating spectrometer is located in a SOEP to maintain the optical axis of the instrument coincident with the mean solar vector. Radiation from the entire solar disk illuminates six gratings clamped together with parallel planes of dispersion and a common angle of incidence. The 170A to 1700A spectrum is divided into six overlapping ranges determined by the ruling (lines/mm) of the six gratings.

The dispersed radiations from the gratings are separated by a six-channel collimating slit system which is driven mechanically in 512 discrete steps through a 12-degree rotation. For each collimator position, only radiation of the wavelengths determined by the diffraction angle will be transmitted by the collimator to six photocathodes in two photomultiplier tubes. The output pulses from the photomultiplier tubes are related to the input solar flux at the appropriate wavelength. The scanning may be commanded to execute only 37 steps instead of the 512 about one of 32 selectable positions (wavelengths) for increased observation of temporal variations of intensities.

D-21 SOLAR X-RAY STUDY, R. W. Kreplin, NRL

Measuring the solar x-ray energy input to the Earth and its variations in order to understand the geophysical parameters of the upper atmosphere is the objective of this experiment. Changes in the solar radiation are one of the primary environmental influences affecting the ionosphere. In particular, solar x-ray bursts accompanying flares and active prominences are the direct cause of increased D region ionization, which in turn is responsible for radio fadeout, sudden cosmic noise absorption (SCNA), and other manifestations of the sudden ionospheric disturbance (SID) event. By establishing a set of x-ray indices of solar activity, correlation with other geophysical phenomena can be made. A study of time variations in solar events and perhaps a more quantitative method of classifying solar events can be made by use of these indices (size classification of flares provides a poor measure of the ionospheric effects of flares.) The time variation of emissions with the four wavelength bands monitored ($0.5\text{-}3\text{\AA}$, $2\text{-}8\text{\AA}$, $8\text{-}16\text{\AA}$, $44\text{-}60\text{\AA}$) play an important role in the formation and variations in the D and E regions of the ionosphere and appear to constitute the predominant strongly variable component of solar radiation reaching the lower ionosphere.

Four ionization chambers are located in an SOEP. The chambers are band sensitive photometers, with the bandwidth defined by the properties of the window material and type of gas within the chambers as well as other factors such as gas pressure, the chamber depth and mass absorption coefficient.

OGO-IV EXPERIMENTS

D-02 (Helliwell, VLF Noise and Propagations)

Katsufakis, J., "Differences Between the VLF Magnetic and Electric Field Spectra of the Lower Hybrid Resonance (LHR) Emissions and Associated Phenomena," submitted for presentation at the 1968 Spring URSI Meeting, Washington, D. C.

ABSTRACT: Brice and Smith [1965] suggested that the LHR hiss observed on the Alouette I (electric antenna) is characterized by large electric fields, and that this hiss band is found more often on a receiver fed from an electric or dipole antenna than a receiver fed from a magnetic or loop antenna (Injun III).

Since a very large number (~ 2000) of VLF recordings were available from OGO-II and IV (magnetic antenna), a comparative study of the LHR emissions and associated phenomena as observed on OGO-II, IV, Alouette I, Alouette II, and simultaneous ground VLF recordings was undertaken. The results of this study are the following: 1) the LHR hiss band as discussed by Brice and Smith has never been seen on any of the OGO-II and IV VLF recordings; 2) anomalous-dispersion whistler traces associated with the LHR were observed on Alouette I and II and on OGO-II and IV; and 3) the anomalous-dispersion whistler traces observed on OGO-II and IV lend themselves more readily to quantitative analysis, since the LHR hiss is not observed and does not mask out pertinent features of the traces.

The conclusion by Brice and Smith that the LHR hiss is generated in the immediate vicinity of the satellite is still supported. The new and intriguing dispersion anomalies being observed have not yet been interpreted, but possible propagation factors will be discussed.

Muzzio, J. L. R., "Reflection of Whistlers in the Ionosphere," submitted for presentation at the 1968 Spring URSI Meeting, Washington, D. C.

ABSTRACT: Evidence for reflection of downcoming whistlers in the upper ionosphere was found in some VLF recordings of OGO-II and OGO-IV. The frequency-time curve of the whistler follows the Eckersley approximation from higher frequencies down to a region where it starts departing towards increased time delays. After passing through a minimum frequency, the signal rises again, sometimes by ~ 200 Hz. For the observed occurrences the satellite height ranges from 450 to 600 km and the minimum frequencies from about 400 to 550 Hz. This corresponds to the region of the first cutoff frequency of the "fast" mode below the proton gyrofrequency. For a downward propagating ray, the refractive index drops considerably in this region and the reflection takes place for frequencies just above the cutoff frequency. The whistlers in question have a dispersion of about $30 \text{ sec}^{1/2}$, which, for the latitudes of observation ($\sim 40^\circ$ geomagnetic latitude) suggests an origin in the conjugate hemisphere. An estimate of the H^+ percentage may be made from a knowledge of the reflection frequency and the local magnetic field intensity. The effects described were reproduced very-closely using ray tracing techniques for an assumed model ionosphere with ducts. The presence of ducts was found necessary in order to guide the lower part of the frequency spectrum to the satellite height. Without the ducts the energy in the lower frequencies would be reflected much higher (resulting in an MR whistler) and would not reach the satellite.

D-05 (Smith, Low-Frequency Magnetic Field Fluctuations)

Smith, E. J., R. E. Holzer, J. V. Olson, and R. K. Burton, "Measurements of Magnetic Fluctuations between 1 and 1000 Hz in the Lower Magnetosphere," submitted for presentation at the 1968 Spring AGU Meeting, Washington, D. C.

ABSTRACT: Two Orbiting Geophysical Observatories have been injected into polar orbits. OGO-II, launched in October 1965, varies in altitude between 400 and 1400 km while OGO-IV, launched in July 1967, varies between 400 and 900 km. Both observatories contain triaxial search coil magnetometers that measure naturally-occurring field variations in the frequency range from 1 to 1000 Hz. Information from a five frequency spectrum analyzer provides near-continuous monitoring of such fields in digital form using an on-board tape recorder. Analog signal waveforms, suitable for

detailed analysis, are also available from the OGO Special Purpose Telemetry. The OGO data contain discrete signals such as whistlers, including ion cyclotron whistlers, and emissions. Intense, broad-band signals are also observed in the form of high latitude chorus. The preliminary analysis of the signals present above the ionosphere in this frequency range, including representative frequency spectra, will be reported.

D-11 (Hoffman, Low Energy Auroral Particles)

Hoffman, R. A., and D. S. Evans, "Field Aligned Electron Bursts at High Latitudes Observed by OGO-IV," accepted for presentation at the 1968 Spring Meeting of the AGU, Washington, D. C., GSFC X-611-67-592, Preprint.

ABSTRACT: In a series of passes in the northern high latitude region, short bursts of radiation were observed in the energy range 0.7 to 24 kev by detectors aboard the polar orbiting satellite OGO-IV. Among these bursts were a number in which the pitch angle distributions at 2.3 kev displayed a maximum at small angles to the magnetic field lines. From the distributions and energy spectra it is argued that a possible source mechanism for these particles is electric fields parallel to the magnetic field lines at distances of several earth radii. The source particles would then be the ambient thermal plasma, with two markedly different temperature components, one at a few ev, from which the field aligned radiation originates, the other greater than an order of magnitude hotter, which produces the isotropic portion of the pitch angle distribution.

OGO-IV TECHNICAL PAPERS

Bingham, R. G., W. C. Erickson, R. L. Howard, J. Lezniak, D. M. Sawyer, and W. R. Webber, "Two Satellite-Borne Cosmic Radiation Detectors," *IEEE Transactions on Nuclear Science*, NS-13, 478, 1966, University of Minnesota Technical Report CR-84, October 1965.

ABSTRACT: Cosmic radiation telescopes constructed at the University of Minnesota will be flown on the Polar Orbiting Geophysical Observatories, POGO C and D, and on the Pioneer Deep Space Probes C and D. These experiments are designed to measure the differential energy spectra of protons, helium nuclei and heavy nuclei up to a charge $Z=14$ in the range 1.0 to 1200 MeV per nucleon. The POGO telescope utilizes a combination of scintillation and Cerenkov counters together with a semiconductor detector. Use of the thresholds in the geomagnetic field extends the energy range for protons to 30 BeV. A Geiger tube, four lithium-drifted silicon detectors, and a Cerenkov counter comprise the Pioneer telescope.

TRW/STL Experiment Data Book, OGO C and D, for the Orbiting Geophysical Observatory Program, Volumes 1 and 2, October 28, 1966.